Colonisation of the Mariana Islands: Affinities and differences between ISEA and Pacific cultures in the 1st millennium BC

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This is my own work, except where otherwise acknowledged.

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Abstract

This thesis examines prehistoric human dispersals from Island Southeast Asia (ISEA) to the Pacific at ~4000-3000 BP by focusing on the colonisation of the Mariana Islands. The Marianas are located in the Pacific Ocean more than 2000 km from ISEA. aThe distant archipelago contains well-preserved archaeological sites dating to the colonisation era that result from one of the very first migrations into Remote Oceania. Ceramics, particularly the distribution of red-slipped and surface marked pottery, have played a central role in archaeological models used to track the Neolithic migration of Austronesian speaking people from Taiwan to eastern ISEA. In addition to movements in ISEA, Austronesian colonisation also spread to Western Micronesia and the Bismarck Archipelago, which was the origin point of Lapita settlers who colonised islands as far east as Samoa. The most common explanation for this extensive and rapid dispersal (that included the first settlement of remote oceanic islands) is that it was stimulated by the introduction and spread of an agricultural economy that created demographic growth and human expansion. In the last two decades, multi-disciplinary data from archaeology, historical linguistics and genetics has frequently been used to expand our knowledge of Neolithic movement in the Indo-Pacific. However, the excavation and analysis of the oldest archaeological sites is essential to produce a fine-grained picture of human mobility and migration in the region.

The archaeological site of Unai Bapot on Saipan in the Marianas was excavated by the author and colleagues to obtain a large sample of early material culture. This allows us to better understand Austronesian expansion and human colonisation. Analysis of the archaeological remains concentrated on the ceramics and establishing the age of the site's oldest cultural deposits with radiocarbon. Given the important role that prehistoric ceramics have in human dispersal models it is surprising that there have been few detailed attempts to examine pottery relationships within the broader region. A new archaeometric method, involving the thin-section study of pot sherds impregnated with a fluorescence agent, was used to establish whether Bapot pottery vessels were made by coiling or the paddle and anvil technique. The study of ceramic manufacturing technique was extended to four Neolithic assemblages spanning a large part of the Austronesian range (Taiwan, Philippines, Palau, Bismarck Archipelago). In addition, vessel attributes from nine Neolithic ceramic assemblages in ISEA were recorded (form/decorative technique/decorative design/temper). By comparing ceramic

production and stylistic data it is possible to scientifically examine the similarities and differences among the ceramic assemblages and to test hypotheses about the affinities of Neolithic colonists with a possible migration source. The results do not offer strong support for the orthodox model of Austronesian expansion. Significant inter-assemblage variation in the pottery assemblages studied indicate a more complicated and less unified movement than is often described. While there is currently no ISEA assemblage that can be identified as the source of the oldest Bapot pottery, there are regional similarities in manufacture, temper, vessel form and decoration that point to eastern Indonesia-northern New Guinea as a key area where human movement into Remote Oceania first began.

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1. Introduction

1.1. Background

Migration is a key element of culture change throughout human history and is often used as an explanatory model for the spatial distribution of archaeological finds (Burmeister 2000). The study of material culture is the main avenue for identifying prehistoric migration, based on the assumption that particular social groups produce specific types of material culture. In cases where large-scale movements of people occur there is often a breakdown in our ability to accurately trace dispersal and identify the pattern and causes of cultural transformation that accompany such movements. This is particularly the case with the Neolithic dispersal of Austronesian-speaking people moving into Island South East Asia and the Pacific. One of the primary difficulties with tracing dispersal and identifying population movement into new areas is that the attributes we use to identify population expansion are not specific or targeted to deal with material culture change from alternative factors such as: a) the effects of interaction between migrants and other groups and, b) culture change caused by human adaptation to new environments and landscapes.

The aim of this thesis is to track human dispersal into the Pacific and the Mariana Islands by studying material culture, especially prehistoric ceramic. Even with very fine-grained archaeological data and good chronological precision it has often been difficult to distinguish the mechanisms responsible for material culture change. The often fragmentary nature of archaeological data does not assist in telling us why potters chose to manufacture particular types of ceramics at different sites in the Indo-Pacific. Environmental factors have probably played a role, but they are not enough to explain shifts in pottery production and ceramic style. In trying to fill this gap I have used ethnographic studies of pottery production to provide an understanding of how potters respond to different socio-cultural and environmental circumstances that might affect production.

Remote Oceania is a term developed by Roger Green (1991) to describe Pacific islands that required a settlement voyage in excess of 350 kilometres of open ocean. The Marianas were evidently colonised from a continental landmass in the Indo-Pacific representing an early voyage to Remote Oceania of more than 2000 kilometres, which is the longest known open sea-crossing at that time in the world (Rainbird 2004:85).

Current evidence indicates that canoe voyages of such length were never made routinely in the prehistoric Pacific and long range passages are instead associated with the colonisation of small and isolated islands in East Polynesia more than two millennia later (Anderson 2000).

Figure 1. Sites discussed in this thesis: (1) Chaolaiqiao, Taiwan, (2) Reranum, Batanes Islands (3) Nagsabaran, Philippines, (4) Irigayen, Philippines, (5) Dimolit, Philippines, 6) Unai Bapot, (7) Ulong, Palau, (8) Bukit Tengkorak, Borneo, (9) Leang Tuwo Mane'e, Talaud Island, (10) Uattamdi, Kayo Island, Moluccas, (11) Minanga Sipakko, Sulawesi, (12) Kamassi, Sulawesi, (13) Ambitle, Anir Island (14) Pulau Ay, Banda Islands, Moluccas, (15) Matja Kuru 2, East Timor.

Prehistoric pottery is a well-known and frequently studied category of material culture that has been used to elucidate and track human movement in the Indo-Pacific for decades, most notably in demonstrating that the Lapita culture represents a major migration event that spanned islands covering more than 4000 linear kilometres of the west and central Pacific (Kirch 1997, 2000). Not only is pottery the most abundant durable artefact recovered from early sites in the Marianas, it is also, as in other parts of the world, closely associated with the arrival and spread of the Neolithic (Childe 1925, 1929; Papmehl-Dufay 2006; Larsson 2009). Neolithic migration was clearly a significant event in the Indo-Pacific region, since modern Austronesian-speaking people were dominant, even on dispersed islands, by European arrival.

Prehistoric migration is reasonably assumed to result in a high degree of similarity between ceramics at both source and destination as can be seen in historical migration events. In our region, this assumption is reinforced by Lapita ceramics that, notwithstanding some important stylistic differences and emerging regional characteristics (Kirch 2000, Summerhayes 2009), contain recognisable vessel forms, decorative techniques, and designs that indicate a common culture and the substantial transmission of the ceramic repertoire between islands spread over thousands of kilometres of the Pacific Ocean.

Previous studies of pottery from Island Southeast Asia (ISEA) and parts of the Pacific have been used to construct a hypothesis that links red-slipped decorated pottery with a vast migration of Neolithic people speaking an Austronesian language and practising agriculture. The migration spread from Taiwan to eastern ISEA, with dispersals to Western Micronesia and the Bismarck Archipelago, which was the origin point of Lapita settlers who colonised islands as far east as Samoa (Bellwood 2011; Spriggs 2011a).

The oldest known pottery in the Marianas has been compared to the better known ceramic assemblages of the Lapita culture in the Bismarck Archipelago to assess whether the two population dispersals are distinct unrelated events or are closely connected migration events as suggested by recent and earlier research (Butler 1995; Craib 1999; Carson *et al.* 2013).

In addition, comparison of Marianas pottery, especially the small decorated components of assemblages, with ceramics from ISEA has been made to investigate the specific origins of the people who colonised the Marianas, after recent studies have proposed a migration from the northern Philippines (Hung *et al.* 2011; Carson and Kurashina 2012; Carson *et al.*2013).

Thus, the oldest sites and ceramics from the Marianas are central to understanding the nature and extent of Neolithic expansion in the Indo-Pacific, particularly questions about the cultural unity of Austronesian expansion, whether maritime dispersal was linked to the introduction of agriculture, and the relationship among pottery-making communities who were geographically separated from each other, often by large stretches of ocean.

Many of the issues in Pacific archaeology are also common to archaeologists working elsewhere in the world. Research themes in our region include human evolution and migration, development and diversity of maritime, agricultural and complex societies, and the effects of cultural contact, colonialism, and globalisation in a vast array of cultures, in addition to understanding human impacts on island and coastal ecosystems (Erlandson 2010:113).

The origin of the people that settled Near and Remote Oceania and the timing of human arrival, have been the subject of intense debate since the first Europeans arrived in the 16th century. Archaeology as a discipline is relatively new to the Pacific but has, since the introduction of radiocarbon dating in the 1950's, become well established and led to major advances in our understanding of the first colonists (Kirch 1997).

Ceramic assemblages have provided fundamental knowledge about migration, especially in areas like the Bismarck Archipelago in Near Oceania where the focus has been on the study and analysis of red-slipped, highly decorated ceramics which feature intricate dentate stamped, repeating geometric patterns that occasionally include anthropomorphic faces and figures. This culture is named Lapita, after an archaeological site in New Caledonia, where one of the first findings of this distinctive pottery was discovered in the 1950's (Kirch 1997). A similar red-slipped ceramic style, also with dentate stamped decorations, occurs in the Mariana Islands in western Micronesia, ~2000 kilometres north-west of the Bismarck Archipelago at approximately the same time.

It has been suggested that the people who manufactured these red-slipped ceramics in both the Bismarck Archipelago (Lapita) and in the Mariana Islands were Austronesian speaking people who started migrating from a "homeland" in Taiwan to ISEA and Oceania in the late Holocene ~4000-3500 before present (i.e. before AD 1950; BP; e.g. Shutler and Marck 1975; Bellwood 1978, 1985, 1997, 2005, 2011; Blust 1976, 1984/85, 1995; Spriggs 1995, 1996, 2003, 2011a; Kirch 2000; Diamond and Bellwood 2003).

Discussion has focused, naturally enough, on establishing the origin, identity and chronology of Neolithic dispersal into ISEA and Near and Remote Oceania. In the last decades a combination of multi-disciplinary data (archaeology, linguistics and genetics) has been used to expand our knowledge of Neolithic expansion. Linguistics and genetics are thought to provide complementary and independent perspectives to that provided by archaeology (Bellwood 2005). This thesis will discuss the above-mentioned disciplines and how they contribute (or not) to understanding the prehistory of the Mariana Islands.

Previous work has focused on the similarities of the décor (decoration) of the pots rather than the technology used by the people who made them. This thesis contributes a new approach by studying the manufacture of pots and relating production techniques to potters and their societal traditions. This thesis uses the notion of *chaîne opératoire* (the operational sequence) which examines how raw materials were chosen and used by potters in order to distinguish variations between ceramic assemblages resulting from deliberate choices of materials, which could reflect the potter's *savoir faire* (know how) and indicate different cultural approaches to pottery production. It is argued that manufacturing differences between early potting groups provide new insight into prehistoric migration and dispersal. In combination with conventional stylistic approaches, we can more fully understand early human movements in ISEA and Near and Remote Oceania.

1.2. Research questions

The research questions addressed in this thesis focus on establishing the timing, origins, and possible motivation for a human migration to the Mariana Islands as discussed below.

1.2.1. When were the Mariana Islands colonised?

Human arrival in the Mariana Islands has been placed at 3500 cal BP by archaeologists for more than three decades (Spoehr 1957; Butler 1995: Rainbird 2004; Carson 2008, 2014), but there are relatively few early sites in the archipelago that can be said to be adequately dated after applying common acceptance/rejection criteria for 14C dates that have become routine in other parts of the Pacific (Anderson 1991; Spriggs and Anderson 1993; Clark 2004). For example, the corpus of radiocarbon ages associated with the oldest sites in the Marianas contains determinations on charcoal not identified to species that could include results on wood from long-lived trees, charcoal samples from several archaeological contexts and material of uncertain provenance. For marine samples, there is uncertainty regarding the magnitude of the local 14C "reservoir" (Delta R), and the accuracy of dating sites with marine taxa such as naturally deposited *Halimeda* bioclasts and limpets. Animals that use a radula to scrape food from limestone substrates (which could be incorporated in the organism's shell), could produce age results that are too old (Petchey and Clark 2010, 2011).

Establishing the date of initial colonisation in the Marianas is a critical issue. A long-held and deeply entrenched view of human arrival in the Marianas ~3500 cal BP suggests that human occupation predates Lapita colonisation of the Bismarck Archipelago and therefore the Marianas assemblages are a potential ceramic 'ancestor' of the first Lapita pottery assemblages in the west Pacific.

The appearance of dentate-stamped Lapita pottery in the Bismarck Archipelago is under constant revision and has been placed, variously, at 3300 cal BP (Specht and Gosden 1997), 3450-3350 cal BP (Specht 2007) and 3470-3250 cal BP for Mussau Island (Denham *et al.* 2012). Several researchers now doubt that Lapita ceramics are older than 3300 cal BP (Spriggs 2011b; Summerhayes 2007, 2009; Specht, personal communication, 2014), and the most recent suggestion is that Lapita in New Guinea may be as recent as 3200-3100 cal BP (Torrence and Specht 2015). The younger age of Lapita sites in recent chronological work suggests that the red-slipped ceramics and rare dentate-stamped pottery found in the earliest cultural layers in the Mariana Islands are a plausible source for the complex dentate-stamped pottery vessels synonymous with Lapita culture (Carson *et al.* 2013), provided the first Mariana assemblages were made several hundred years before the advent of Lapita in the West Pacific.

However, radiocarbon ages from Unai Bapot and other sites in the Marianas in this thesis are used to revise the timing of human arrival. The analysis of age determinations indicates that colonisation of the Marianas is not as old as 3500 cal BP and may have in fact been roughly contemporaneous with the establishment of Lapita sites in the Bismarck Archipelago.

1.2.2. Where did the original settlers of the Marianas come from?

In ISEA and the Pacific, pottery is a commonly used proxy to infer the presence of Austronesian language speakers and the Neolithic cultural traits they are thought to have brought with them during a migration. The pottery from early sites in the Marianas is a red-slipped or red polished ware dominated by small carinated jars with everted rims. Vessels are occasionally decorated with dentate-stamped and circle-stamped impressions and these traits have been argued to have generic similarities with pottery from Lapita sites in the Bismarck Archipelago, and red-slipped decorated ceramics from Neolithic sites in northern Luzon in the Philippines. Recently, researchers have debated whether or not ceramic similarities support a direct dispersal model featuring an initial movement from the northern Philippines to the Mariana Islands (~2500 kilometres), followed by a second migration from the Mariana Islands to the Bismarck Archipelago (~1900 kilometres; Carson 2014; Carson *et al.* 2013). Such a migration involving a total journey of 3400 kilometres of Pacific Ocean and involving two long-range passages, each of which on their own is greater than any voyage needed to reach islands colonised by Lapita groups, suggests a highly developed maritime capacity that was otherwise not employed to reach any other parts of Remote Oceania such as Pohnpei and the Society Islands. Even more perplexing is that Palau and Yap appear to have been settled independently from other parts of the Indo-Pacific although they are the closest islands to the Marianas (Intoh 1997; Rainbird 2004).

To assess the cultural relationship of different Neolithic groups in the Indo-Pacific, the Bapot site material is compared to prehistoric assemblages (mainly ceramics) from Chaolaiqiao in Taiwan; Nagsabaran in northern Luzon, Philippines; Ulong, in the

Republic of Palau, and Ambitle in the Bismarck Archipelago. The purpose is to investigate whether or not there is a homogenous ceramic craft tradition in the region during the period ~4000-3000 BP that dispersed with related groups of Austronesian potters. The alternative, of substantial heterogeneity in pottery assemblages and ceramic production methods, would suggest that migration was a different and more complex event than has often been assumed (based on previous comparison of a small number of stylistic traits found in widely separated ceramic assemblages).

1.2.3. What factors stimulated colonisation of the Marianas?

The colonisation of the Mariana Islands at ~3500 BP, if true, not only marks the first extension of human occupation to islands in the remote Pacific, but is also notable for being the longest known open sea-crossing of its time. The colonisation movement is often seen as part of an Austronesian dispersal that spread from Taiwan south to the Philippines around 4000 cal BP, then passed through Island Southeast Asia and the Bismarck Archipelago, before finally extending to Remote Oceania (southeast Solomons, Vanuatu, New Caledonia, Fiji, Tonga, Samoa). Most of the dispersal occurred within a millennium from ~4000-3000 cal BP (Bellwood 2011), and it is widely held to be the result of population expansion as a result of farming and population growth (Gray and Jordan 2000; Fort 2003; Diamond and Bellwood 2003; Bellwood 2005, 2011). It has also been suggested that environmental factors such as climatic change, including sea-level rise during the early Holocene inundating habitable coastal land in ISEA, caused people to voyage to locate new land (Nunn & Carson. 2015). Sea-level rise and an increase in the amplitude of ENSO events around 4000 BP, in combination with improvements in maritime technology, are also posited to have been important factors stimulating rapid Austronesian expansion, rather than the emergence of farming (Anderson 2005; Anderson *et al.* 2006; for a different view see Bellwood 2011).

For the Mariana Islands it has been suggested that colonisation was purposeful rather than inadvertent (Hung *et al.* 2011) and the seafaring people of ISEA knew of the archipelago's existence before occupation. However, human settlement only took place when environmental change and sea-level decline exposed coastal flats that were attractive for habitation (Hunter-Anderson 2010. Additional ideas about the colonisation of the Marianas have been proposed by several scholars from different disciplines. Paleoecological records, especially a low frequency of charcoal and increase in grassland plant taxa in sediment cores, suggest human arrival occurred a millennium before the oldest recorded archaeological sites (Athens and Ward 2005). Linguistic studies also indicate that the colonisation of the Marianas was early and dates to the beginning of Austronesian dispersal; some phonological lexical morphosyntactic evidence suggests the Chamorro language represents an early split from Proto-Malayo Polynesian (Blust 2000). Genetic results also suggest that the Marianas may have been settled between 5000 and 3500 years ago directly from ISEA, particularly parts of Wallacea (Sulawesi and the Moluccas) where haplotype lineages similar to those in Chamorro groups are found (Vilar *et al*. 2013). Computer simulation of ancient voyaging also favours the Wallacea area as the starting point for direct voyages to the Mariana Islands, since more northern starting points for canoe voyages fail to reach the Marianas (assuming similar climate conditions occurred in the past) due to the direction and strength of prevailing winds and currents (Irwin 1992; Fitzpatrick and Gallaghan 2013). In short, major questions regarding prehistoric migration, including the fundamental issue of the origin and timing of human settlement in the Marianas, have yet to be answered. This thesis represents a new research approach using early pottery production techniques to track maritime migration in tandem with a critical review of the chronology of Neolithic dispersal (Chapters 5.4 - 9).

1.3. Thesis structure

As mentioned previously this thesis examines the early human colonisation of the Mariana Islands in Western Micronesia to understand (1) when people first arrived in the isolated archipelago, (2) where the colonisers came from, and (3) the factors that may have stimulated initial migration to small and remote islands in the Pacific.

1.3.1. Timing

The important issue of when first human arrival occurred in the Mariana Islands is examined through the analysis of 20 radiocarbon determinations from the 2008 Bapot 1 excavation. These will be discussed within their own context and in comparison with radiocarbon dates from previous excavations at Unai Bapot and other early sites in the Mariana Islands (Chapter 7). Setting the date of first human arrival in the Marianas is critical for understanding the colonisation of the Mariana Islands in relation to the concept of a "Neolithic Austronesian expansion" into ISEA and the Bismarck Archipelago (the Lapita culture).

1.3.2. The oldest sites

A large archaeological data set was assembled by excavating and analysing archaeological remains from the Bapot 1 site at Laulau Bay on the east coast of Saipan in the Mariana Islands. The assemblage of cultural remains from the Bapot site provides baseline information about early human settlement, including when people first inhabited the site and what their material cultural assemblage looked like (Chapter 7).

Bapot is acknowledged to be one of the oldest sites in western Micronesia and there have been at least four excavations made at the site to recover evidence of initial occupation (Spoehr 1957; Marck 1978; Bonhomme and Craib 1987; Ward 1985; Carson and Welch 2005).

Second, the oldest sites in the Marianas were studied using information in published papers and contained in numerous unpublished excavation reports produced by resource management projects ahead of development. This information was used to investigate variation among early Mariana sites, particularly if there was evidence for a cultural assemblage that predates Bapot. Some paleoenvironmental data suggested the possibility of human colonisation around 4000 years ago while several archaeological sites, including Bapot, have been dated (controversially, as this thesis shows) to as early as 3600-3500 cal BP. What are the characteristics of the oldest sites in western Micronesia, and is there plausible evidence of human arrival in the Marianas centuries before any other part of Remote Oceania was colonised (Chapter 8)?

1.3.3. The ceramics

This thesis documents the ceramic sequence of Unai Bapot with emphasis on the earliest deposits with particular regard to possible ceramic origins. This was done by conducting a detailed analysis of vessel morphology, décor, petrography, choice of raw material (clay and temper) and manufacturing methods (Chapter 9). The ceramic production techniques identified at Unai Bapot are then compared with those seen in sites in the Marianas and the techniques identified at Neolithic sites in Taiwan, the northern Philippines, Palau and Ambitle Island in the Bismarck Archipelago. Sherds which had an approximately similar age to ceramics from Bapot were examined in thin section to understand how manufacturing techniques varied at different locations along with details of vessel form and decoration.

The ceramic dataset was used to examine the similarity or dissimilarity of Bapot pottery with ceramics from other parts of the Indo-Pacific, to construct a new model of Neolithic migration. The main methods used involved the recording and numerical analysis of design, vessel type and typology, as well as microscopic analyses allowing determination of clay and temper source similarities, and a discussion about raw material choice and manufacturing methods in Chapter 9. The purpose of making such a study was to use a new approach to investigate cultural linkages by comparing early Neolithic ceramics from different parts of the Austronesian range (Taiwan, Northern Philippines, Palau and the Bismarck Archipelago) and which date to the major phase of expansion (~4000-3000 BP).

Furthermore, the non-ceramic artefacts from Unai Bapot (lithics and shell) were described and studied. A detailed analysis including thin sections and microscopic and petrographic descriptions of stone artefacts is presented. The non-ceramic artefacts (stone, shell, sea urchin) deriving from the 2008 excavation at Bapot 1 are discussed in Chapter 7). Non-ceramic artefacts and radiocarbon results will be discussed in relation to the results of previous work at Bapot and other early sites in the Marianas (See Chapters 6, 7 and 10).

2. Theoretical perspective

This chapter discusses theoretical concepts central to my study on the early colonisation of the Mariana Islands. These concepts relate to: *culture*, *migration* and what is encompassed by the historical expression of *the Neolithic*. The meaning and derivation of these three concepts is fundamental to interpretation of the archaeological record of the Mariana Islands and more broadly to hypotheses of Austronesian migration. They apply, particularly, to the concept of *chaîne opératoire*, or the operational sequence, related to the ceramic production study used in this thesis (Chapters 9-10).

At its root, the purpose of archaeology is to investigate, interpret, and hopefully, to understand past human behaviour. In order to do this, the archaeologist examines remnants of material remains. Remains of pottery, textiles, basketry, stone or shell artefacts, plant, animal and sometimes human remains, alongside various dating techniques such as radiocarbon dating are used to create a picture of the past and a history of the people who left behind the physical remains. The physical remains are used to understand the cultural and social identity of populations and the mechanisms of their interactions and migrations. However, the materials recovered by archaeologists and the scientific methods used to interpret them, do not of themselves provide the whole story of past human behaviour.

The archaeologist has to make sense of the preserved material and the results of the interpretive frameworks that provide a historical narrative. Since its development in approximately the 16th century (Thomas 1989), archaeology has undergone continuous theoretical reassessment as our interpretive frameworks are refined, dismantled and renewed. To understand archaeology today, it is important to examine how theories and frameworks have interpreted prehistoric remains and built narratives of human behaviour, particularly about migration (Swete Kelly 2008).

2.1. Culture history and identity: a background

Cultural history and cultural identity are fundamental concepts of modern archaeology. The use of the word 'culture' to describe artefacts and social constructions associated with particular groups of people first appeared in archaeology in the late 19th and early 20th centuries. The German philologist and archaeologist Gustaf Kossinna used artefact types and their distribution to trace the origins of modern European races. Kossinna proposed that the similarities observable in artefact types and other material remains was not the result of chance or coincidence. He suggested that what appeared to be a consistent 'type' in artefactual remains was indicative of common origin for the artefact, and that they were made by a single unified group of people. Kossinna called clusters of like material remains a 'culture', and extrapolated the nomenclature to include the people who made them (Kossinna 1911)

Similarities in material remains were termed a *culture* and thus, in Kossinna's formulation, a 'culture' was more or less analogous to *ethnicity*, or *ethnic group* or *race*. Kossinna's interpretations of archaeological material and its link to cultures, were, unfortunately, tainted when his ideas were embraced by the Nazi regime in Germany during the late 1930s and used as evidence of the supremacy of one 'race' over others. Kossinna was largely inspired by a paper by the Swedish archaeologist Oscar Montelius (1884) that examined the origin of the Nordic people by using artefact typologies to argue that the Nordic people and their cultures originated in the Near East, and progressed from there to southern Europe, continuing northward before they finally reached Scandinavia.

Montelius's work reflects the prevailing social attitudes and central questions surrounding 'race' or 'ethnicity' that arose during the late 19th century (Papmehl-Dufay 2006:25). Montelius's work on typology and chronology, and Kossinna's theoretical approach to archaeology and human cultures influenced one of Australia's founding archaeologists Gordon Childe (1925). Childe was inspired by Montelius to attempt a systematic explanation of European prehistory. He believed that the distribution of material cultural remains reflected the distribution of groups of people. However, Childe explicitly rejected Kossinna's ideas about 'race' (Childe 1929:v-vi). He identified 'culture groups' or 'cultures' from types of material remains that repeatedly occured together as 'packages'. a. Childe argued that Neolithic cultures possess "certain types of remains – pots, implements, ornaments, burial rites, house forms – constantly recurring together" (Childe 1929: p. v-vi). He developed an economic model to explain the shift from the Palaeolithic to the Neolithic, where the driver was the domestication of plants, and the development of agriculture. The change from nomad hunter-gatherer to settled farmers cultivating domesticated crops resulted in a sharp increase in population density which eventually led to the mass migration of Neolithic communities to land suitable for farming. In recognition of the significance of agriculture to human history, Childe (1929, 1936) termed his model the 'Neolithic revolution'.

Childe's definitions of culture and the Neolithic Revolution had a profound impact on modern archaeological theory and practice and are still central pillars of the discipline. His logical arguments for identifying, tracing and naming cultures are fundamental to much modern archaeology. They also laid the foundation for the concept of 'culture' to replace the concept of race (Papmehl-Dufay 2006).

The 1960s saw a new theoretical movement in archaeology. Originating in America, the movement became known as the 'New Archaeology'. In the New Archaeology, 'culture' was regarded as an adaptive mechanism. Differences in material culture were interpreted as the response by the human inhabitants of a region to a particular prevailing environment. Environmental variability was understood to contribute to, and explain, the diversity of cultures in prehistory (Binford 1962). European archaeologists did not accept this approach until later when it was associated with Processual Archaeology. Processual Archaeology avoided a focus on 'race' or 'ethnicity' in reference to the concept of 'culture'.

The British archaeologist David Clarke was strongly influenced by ecology, adaption and classifications used in the natural sciences. Clarke took a conservative position when he stated that: "An archaeological culture is not a racial group, nor a historical tribe, nor a linguistic unit, it is simply an archaeological culture" (Clarke 1968). Clarke's thesis grew in popularity, and the concept of an 'archaeological culture' comprising only the material remains of an archaeological site became a fundamental platform in the discipline. This interpretation of 'culture' was dominant in discussions of the Neolithic from the New Archaeology in the 1970s (Papmehl-Dufay 2006:26). Clarke broke away from the artefact-dominated culture-historical approach of his contemporaries, and argued that by studying how human populations adapted to their environments we can understand many aspects of ancient society (Renfrew and Bahn 1996:35). As a result, emphasis shifted away from a cultural historical focus describing artefacts and their links to people, to explaining the processes of cultural change (Swete Kelly 2008:38). 'Culture' was now regarded as representing an adaptive mechanism that reflected access to raw material available in the local natural environment.

In the 1980s, discussions around theoretical archaeology burgeoned. The concept of 'culture' once again became a topic debated by archaeologists. However, archaeologists broadened the concept to encompass 'cultural identity', arguing that the New Archaeology had been too narrow in its definition and focus, and therefore failed to consider all of the aspects of a human culture and the reasons for cultural change. The New Archaeology, for example, provided no explanation for variation in the material culture of people living in the same ecological habitat. Neither was there consideration of the 'humanity' of the individuals or groups that produced the artefacts nor a psychological element in the variation of material culture (Trigger 1993:361). The critique of the New Archaeology (that is Processual Archaeology), became known as 'Post Processual Archaeology'. Post Processual Archaeology argues that the interpretation of cultural material remains is a hermeneutic exercise, which means that we, as archaeologists, 'assign' meaning to archaeological cultural material and the behaviours of ancient peoples using ethnographic analogy from the present day, and our own cultural ontology to inform our interpretation of remains (Szabo 2006:44).

Post Processual Archaeology asserts that 'native' material objects may play an active role in human societal processes such as communication, and are often indicative markers of major social change within a cultural group or 'race'. Hodder has argued that the cultural meaning of material objects is dependent on a number of social factors and the interpretation of these patterns in a situation of archaeological recovery of artefacts is highly problematic (Hodder 1992: 185). Material culture is not static, and the variations in cultural material plays an active role in the formation of social structures and the expression of the 'culture' associated with them (Papmehl-Dufay 2006:29). Ian Hodder argued that some distributions of material culture are specific to a cultural group, while other distributions readily cross social boundaries (1982).

Post Processual archaeologists such as Christopher Tilley also consider the importance of symbolism in human actions, and argue that material culture is like text. It is written code and the meaning of the text can be ascertained as long as the grammar is correctly understood (Tilley 1991). This view has several problems. Material culture does communicate, however the message communicated, especially to the archaeologist, often hundreds or thousands of years later, is not necessarily the meaning intended by the individual making the object. A text more or less maintains its meaning, and the author, to some degree, retains control over what he/she intended to communicate., An *object* communicates in a much more dynamic way and what is being communicated may change completely depending on the context in which it is found, and the people involved in its examination (Papmehl-Dufay 2006:30).

The above is not an attempt to describe the theoretical development of archaeology; for an introduction to this see Renfrew and Bahn (1996). Instead, the discussion was included to help describe the point of departure of this thesis. While Gordon Childe's theory of the 'Neolithic Revolution' was developed in the 1920s to explain the European archaeological material, it is often used by archaeologists in the Indo-Pacific region to explain a migration from Island Southeast Asia (ISEA) to the southeast Solomon Islands and Samoa (Remote Oceania) at approximately 4500-3000 BP (Diamond and Bellwood 2003; Bellwood 2005). In the archaeology of both these regions, material culture similarities have been used as evidence for the migration of peoples. In ISEA and the Indo-Pacific, pottery is used as a proxy for both the presence of migrating Austronesian language speakers, and the Neolithic cultural traits that they are thought to have possessed (Swete Kelly 2008:28).

The main 'Out-of Taiwan' model (Shutler and Marck 1975) is used to explain the rapid dispersal of Austronesian culture. It is widely held that this rapid expansion results from the demic diffusion of agriculturalists (Gray and Jordan 2000; Fort 2003; Diamond and Bellwood 2003; Bellwood 2005). Bellwood's Early Agricultural Dispersal Hypothesis and Shutler and Marck's Out-of Taiwan model are both highly influenced by the theory of a 'Neolithic Revolution' in the region and view pottery as a signature of the Neolithic. There have been observations of similarities in pottery style and language both within ISEA and between ISEA and Near and Remote Oceania. These similarities have been explained as the result of migration of an Austronesian speaking people, and that the underlying reason for this migration was agriculture, which required more land than used in nomadic hunter gathering (Bellwood 2005; 2011). This model is very similar to that proposed by Colin Renfrew in his 1987 monograph, *Archaeology and Language: The Puzzle of the Indo-European Origins*.

An alternative model suggested by Solheim (1975) was termed the *Nusantao Maritime Trade and Communication Network* and explains the similarities in cultural material from different locations in ISEA from another perspective. Solheim proposed that trade and exchange were critical factors to explain the geographic distribution of Neolithic traits such as pottery rather than migration. What is clear, though, is that both models are deeply grounded in cultural history.

2.2. 'Out-Of-Taiwan'

The 'Out-Of-Taiwan' model was primarily developed from an in-depth analysis of linguistic and archaeological data. First outlined by Richard Shutler and Jeff Marck (1975) the model was based, in part, on earlier work by Robert Suggs (1960, 1962). Peter Bellwood (1975) suggested a link between Lapita pottery found across the Pacific from Papua New Guinea to Samoa and the pottery found in ISEA. In numerous publications, Bellwood (1975, 1979, 1985, 1991, 1995, 1996, 1997, 2005 and 2011) and Robert Blust (1976, 1984, 1985, 1995, 1996) increasingly combined and correlated the emerging linguistic and archaeological data. Bellwood's 'Out-Of-Taiwan' model is similar to Childe's, which is based on an argument for what was called an 'Early Farming Dispersal', which is still a widely accepted and arguably dominant theory today, to explain the occupation and archaeological record of ISEA and the Pacific (Swete Kelly 2008). The 'Early Farming Dispersal' hypothesis links prehistoric population movement and language dispersal with the development and dispersal of agriculture.

Bellwood (2005) argued that the Austronesian language family must have originated in a fairly restricted area, and was dispersed from there through some degree of population migration which is evidenced by a relatively homogenous, widespread, and stylistically related Neolithic material culture. Furthermore, he proposed that some linguistic traits correlate with the appearance of agricultural and archaeological assemblages (Bellwood 2005, 2011; Swete Kelly 2008). Bellwood divides the development of farming into three different phases: pre-farming, transition to farming and dependence on farming and dispersal. The dispersal is then divided into four different zones: *The homeland zone*, where initial developments occur; Secondly, *the spread zone,* which is created by dispersal of the farming community and is homogenous culturally, linguistically and biologically, and also carries a material culture package; Third is the *friction zones*, which occur during dispersal when farming communities encounter prior populations already settled in an area. The friction zones are characterised by both genetic and cultural interactions between hunter-gatherers and farmers. The last zone is the *overshoot zone*, which occurs when farmers move into a hostile environment, which would often require adaptation to a new environment that is difficult to farm (Bellwood 2005; Swete Kelly 2008).

Bellwood also argues that when a farming community is established in a new area, a reticulated pattern of development takes place. Changes may occur in the community through interactions with other populations; and transformations may arise in material culture due to adoption of a chance modification. This results in a phylogenetic relationship between the parent and daughter communities that implies material culture similarity and difference (Bellwood 2005). Of course, population interaction and chance modification are events that are not unique to migrating farmers and were probably experienced by many groups in the past, including hunter-gatherers.

Based on the farming-migration hypothesis, Bellwood and colleagues argue that Taiwan was settled from south-eastern China by proto-Austronesian speakers, probably from the Fujian or Guangdong provinces somewhere after 5500 BP. After a millennium, at around 4500-4000 BP, the Taiwanese population began to move south to the Philippines passing through the islands of the Batanes in the Luzon/Formosa Strait. After settling in northern Luzon, there was rapid dispersal by one Austronesian group that had made an early move from the northern Philippines to the Mariana Islands in western Micronesia, before a migration to the Bismarck Archipelago (Carson *et al.* 2013). Bellwood proposes that another group passed through the southern Philippines, Kalimantan, Sulawesi, and then moved to Java, Sumatra and the Malay Peninsula, before settling in southern Vietnam. The latter expansion correlates with the distribution of Western Malayo-Polynesian languages. (Bellwood 2005; 2011; Hung *et al.* 2011).

A further migration of Austronesian-speaking people followed the same route south, but went through the Moluccas and on to Lesser Sunda, where Central Malayo-Polynesian languages developed. From this area people migrated to Halmahera where the Eastern Malayo-Polynesian languages developed. Subsequent migration to the West Pacific as far as Fiji-West Polynesia led to human settlement of these islands and spread of Oceanic languages (Swete Kelly 2008:10-11). As these migrations and settlements are thought to have occurred relatively rapidly, this model is known as the 'Express Train' model (Diamond 1988:307-308).

Linguists such as Blust (1993) and Pawley (1999, 2002) support a theory of rapid migration and early settlement of early Malayo-Polynesian language speakers after they left their homeland since there are few linguistic variations in the languages spoken in disparate areas of the Philippines and various parts of Indonesia-Malaysia.

2.3. Alternative hypothesis

Alternatives to the 'Out-of-Taiwan' model have been proposed by Meacham (1995) and Solheim (1975). Meacham suggests a local evolution model that locates the origin of the Austronesian speaking peoples through a cultural convergence process rather than through a movement from the Chinese mainland. He identifies a large triangular area with apices in Taiwan, Sumatra and Timor that is identified as Austronesia, and he proposes that the Neolithic settlement of Taiwan originated from the south in ISEA rather than from China (Meacham 1995:249).

2.3.1. Nusantao Maritime Trade Communication Network

In 1975, the archaeologist Wilhelm Solheim proposed the existence of a maritime trade and communication network, the *Nusantao Maritime Trade Communication Network* (NMTCN). The word 'Nusantao' refers to 'people of the south islands' and is derived from a combination of the Austronesian root word for 'nose', 'nusa', meaning 'south islands' and 'tan' meaning 'man' or 'people'. Solheim coined this word to describe the peoples inhabiting ISEA.

Solheim suggests that a Pre-Austronesian trade language developed around 11000 BP to facilitate economic interaction between the peoples of the areas bordering the South China Sea. At ~7000 BP, Austronesian languages emerged from the Pre-Austronesian zone in coastal Fujian, northern coastal Vietnam, western coastal Philippines, and perhaps as far as southern and western coastal Taiwan (Solheim 1975, 1984, 1985, 1988, 1996, 2006). Solheim (2006) proposes that similar Neolithic pottery and cultural traditions around ISEA are the consequences of the trading activities and migrations of Nusantao traders. Solheim asserts that the earliest pottery in Southeast Asia and the Pacific belongs to the Hoabinhian pottery tradition found in coastal Vietnam, and that this tradition gave rise to subsequent pottery types which developed into the Sa Huynh-Kalanay pottery and Lapita pottery traditions. The main differences between the NMTCN and the 'Out-Of-Taiwan' theory are, first, that the Nusantao people spread south-to-north through the Philippines reaching Taiwan and Southeast China at 7000 BP, and these people were already speaking a Pre-Austronesian or Proto-Austronesian language. Second, NMTCN migration was driven by maritime trade rather than the expansion of farming migrants.

Solheim (2006) also proposed that the Nusantao traders from southern China established the Tapengkeng culture in Taiwan, but as the NMTCN expanded north and south along the Chinese coast 7000-6000 years ago, Taiwan became isolated commercially, and as a consequence of being excluded from the trading group, several distinct Austronesian languages developed there. Solheim also noticed a difference in the cultural records of the Northern Luzon sites and those found in Borneo. He believes two separate networks operated within the NMTCN covering two different geographical spheres. One network linked coastal Vietnam and south China with Taiwan and the northern Philippines, Palawan, the northern Visayas and Micronesia. The other network linked the south coast of Vietnam with Borneo, Indonesia, Mindanao and the southern Visayas. Solheim proposed a model based on pottery found from sites in Southeast Asia, to explain Neolithic development based on internal development where the prime driver of the Neolithic was trade and communication. Further, Solheim suggested that it was not necessary that people physically migrated, but rather they kept in contact and exchanged material, trade goods and ideas through maritime trade networks (Solheim 2006, Swete Kelly 2008:15-16).

The 'Out-Of-Taiwan' model has prevailed for many years as the dominant theory to explain 'Neolithisation' of ISEA and the Pacific, especially the expansion of the Lapita Culture Complex across the Pacific. Solheim's Nusantao model has been largely ignored in the archaeological debate. However, over the last decade, archaeological research has produced more data from ISEA and Papua New Guinea as well as from the Pacific Islands. These data indicate that commercial and social interaction, especially within ISEA and between ISEA and Papua New Guinea, occurred in pre-Neolithic times (Flannery and White 1991; Specht 2005; Ambrose *et al.* 2009; Torrence *et al.* 2009; Denham 2010; Donohue and Denham 2010; Reepmeyer *et al.* 2011; Specht *et al.* 2014.

This dissertation will argue that there is value in Solheim's model of a Maritime Trade Communication Network, although the current evidence is insufficient to uphold the whole model. Interaction and most probably some kind of exchange appears to predate the Neolithic in ISEA and in the Bismarck Archipelago. Several scholars (e.g. Denham 2004; Denham and Donohue 2009; Donohue and Denham 2010; Lebot 1999; Kennedy 2008) have provided evidence for the pre-Neolithic westward expansion of domesticated plants such as banana (*Musa*) and sugarcane (*Saccharum robustum*) from

New Guinea to ISEA. Further, marsupial faunal remains with origins in New Guinea have been recovered in pre-pottery contexts from Timor, the northern Molucca Islands and from Talaud Island (Flannery 1995, 1994). Inter-island movement of obsidian has also been observed from late Pleistocene and mid-Holocene contexts on Timor, Borneo and the Talaud Islands (Ambrose *et al.* 2009; Reepmeyer *et al.* 2011).

2.4. Linguistic research

The 'Out-Of-Taiwan' hypothesis is largely based on historical linguistics, and especially Blust's model of Austronesian subgrouping (Figure 2) in ISEA (Blust 1976, 1978, 1982, 1988). Almost all indigenous populations in ISEA speak languages belonging to the Malayo-Polynesian (MP) branch of Austronesian. The other nine primary branches of Austronesian (Proto-Austronesian) are spoken only by aboriginal Taiwanese (Blust 1999). This suggests that the Austronesian languages originate in Taiwan, and spread from there to current locations, with the various branches of MP separating during expansion (Hill *et al.* 2007:29). In recent years, linguists, especially Donohue and Denham (2010), have criticised Blust's model, and instead proposed a linguistic trajectory of Proto-Austronesian to Proto-Malayo-Polynesian to Eastern Malayo-Polynesian to Proto-Oceanic (Donohue and Grimes, 2008: Donohue and Denham 2010). The implication of including all Western-Malayo-Polynesian languages in an expanded Proto-Malayo-Polynesian group is that, rather than a graduated dispersal of MP languages south of Taiwan, there was a rapid dispersal and propagation of MP languages, and dialects of MP that could have been spoken across most of ISEA. The dispersal centre of MP cannot be identified on purely linguistic grounds and could potentially involve the southern Philippines, the eastern Indonesian area (Blust 1995:458), or the West Pacific (Donohue and Denham 2010:226-27).

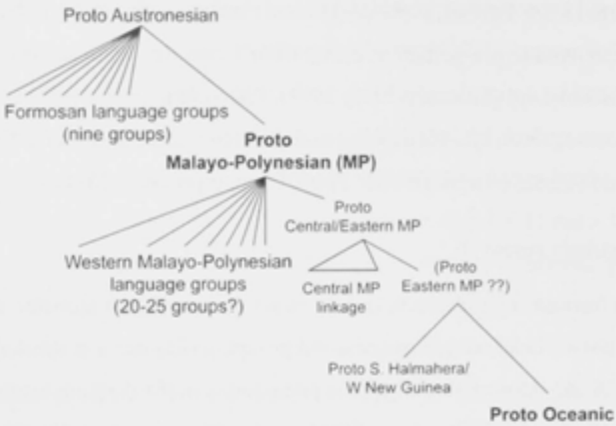


Figure 2. Austronesian language phylogeny (from Pawley 2007, after Blust 1995).

Despite the popularity of idea of a culturally, linguistically and biologically homogenous farming community that migrated from Taiwan to ISEA at 4000 cal BP, the model has little support from DNA research on mitochondrial DNA. Hill *et al.* (2007) conducted a large study of 929 mitochondrial DNA (mtDNA) samples from ISEA. Results showed that the biological diversity in the region is extremely high, and includes a large number of indigenous clades. Most of the mtDNA data support a human dispersal in the late Pleistocene or early Holocene, rather than in the mid-Holocene. Only some 20% of modern mtDNA could be linked to a human dispersal from Taiwan. The mtDNA *does* show a closer biological link to Taiwan than to mainland Asia, but if there had been a large, homogenous human dispersal from Taiwan 4000 years ago that assimilated indigenous populations in ISEA, it should be reflected in a more homogenous mtDNA signature (Hill *et al.* 2007:29).

Most archaeologists working in ISEA and the Pacific agree that something major happened at around 4000-3000 cal BP in the Indo-Pacific region. There is an ongoing debate about the origins, timing and manner in which various traits of Neolithic culture became dispersed throughout island Southeast Asia, although the Neolithic is often defined merely by the occurrence of pottery and very few cereal remains have been found at sites (Bulbeck, 2008; Anderson 2005:26; Paz 2002:279).

The orthodox theory of Taiwan as the homeland of the Austronesian languages developed by Shutler and Marck (1975) and refined by Bellwood (1978, 1985, 2005,

2011) has met with very little criticism, and it is now widely accepted that the location source of Austronesian is Taiwan (Donohue and Denham 2010). Since the mid 1970s the 'Out-Of-Taiwan' theory has been explained as driven by agricultural dispersal in much the same way as Renfrew's (1987) theory of Indo-European Neolithic expansion. For the last decade, the debate has focused on the rate and cause of the rapid dispersal of Austronesian-speaking peoples.

An influx of a dispersing population fuelled by agriculture and modelled by demic diffusion into ISEA has recently been opposed by archaeologists, linguists, and others (Bulbeck 2008; Denham and Donohue 2010; Denham *et al*. 2012; Hill *et al.* 2007). Hypotheses of pre-Neolithic maritime trade networks, not unlike Solheim's model, that facilitated the rapid spread of Austronesian languages and red-slipped ceramics, deserve consideration.

2.5. Dawn of agriculture

The cultivation of rice and millet had begun in central mainland China by at least 8000 BP (Chang 1986; Yan 1991, 1992; Shih 1992; Bellwood 2007). By 7000 BP, red-slipped and cord-marked ceramics, pedestals, stone adzes and stone reaping knives are found in the coastal regions of Fujian and Guangdong, and by 5000 BP the first evidence of rice cultivation is found at the coastal site Shixia, in Guangdong Province (Bellwood 2007:208). From mainland China, agriculture spread to Taiwan. The early Neolithic immigrants to Taiwan, denoted the 'TPK' culture after Tapenkeng (now Dabenkeng), settled in coastal zones where a corded-ware pottery was defined (Chang *et al*. 1969). The first TPK archaeological sites contain evidence of fishing, foraging and limited horticulture prior to 5000 BP (Carson and Hung 2014:507-510). Archaeological research in Taiwan has documented several sites in deep alluvial plains at the Tainan Science-based Industrial Park in southwest Taiwan from which abundant charred rice and foxtail millet samples from the fifth millennium cal BP have been collected (Tsang, 2007; Bellwood, 2011; Bulbeck 2008; Carson and Hung 2014:507).

The Neolithic in Taiwan can be simplified by dividing it into three phases, which can be divided further into different cultures (see Table 1, after Hung 2008:58). The Middle Neolithic culture of Taiwan is characterised by fine cord-marked ceramics, and the emergence of red-slipped ceramics (some red-slipped pottery also occurred during the early Neolithic), pottery spindle whorls, chipped axes, polished adzes (some of which are stepped), knives, stone needles, grindstones, arrowheads, net sinkers and jade ornaments, lingling-o (ear ornaments), domesticated pig (*Sus scrofa*), domesticated dog and rice (Bellwood 2011; Hung 2008).

Table 1. Phases of Neolithic development in Taiwan (modified after Hung 2008:23).

Phase	Date	Pottery/Culture	Regions
Early Neolithic	5500-4500 BP	Thick cord-marked pottery Dabenkeng culture	Along the coast of Taiwan
Middle Neolithic	4500-3500 BP	Fine cord-marked pottery	
		Xuntangu culture	North
		Niumatou culture	Central-west
		Niuchouzi culture	South
		Fushan culture	East
Late Neolithic	3500-2000 BP	Plain pottery, sometimes decorated	
		Yuanshan culture	North
		Zhishantan culture	North
		Yingpu culture	Central-west
		Bahu culture	South
		Beinan culture	East

Taiwan's Middle Neolithic resulted in a greater number of sites than previous periods, especially on the east coast. Here the sites grow much larger, and a sevenfold increase in site numbers is documented (Hung 2008). A proposed explanation for this is escalating rice and millet farming. The switch from foraging to Neolithic farming is thought to have led to population pressure on the relatively small island of Taiwan (Carson and Hung 2014:509). Suggested overpopulation, fuelled by agriculture, has led researchers (Bellwood 2011; Carson and Hung 2014) to propose that Taiwan was the homeland of migrating agricultural people moving into Island Southeast Asia by 4000 cal BP, and then migrating from there to the Pacific.

The proposed route based on archaeological finds of red-slipped bowls with ring foot bases, starts on the eastern coast of Taiwan where such ceramics occur at sites such as Chaolaiqiao at ~4200 cal BP. Red-slipped pottery is next found in the Batanes Islands south of Taiwan in the Bashi Strait, slightly before 4000 cal BP. The early dates for the Batanes Islands have been criticised for not following chronometric hygiene by Anderson (2005), who suggests a much younger date for occupation of the Batanes

Islands. From the Batanes Islands the specific red-slipped ceramics may have reached Northern Philippines as early as 4000 cal BP, and several pottery-bearing sites with early dates are found in Cagayan Valley, such as Andarayan ~4000-3400 cal BP, Magapit ~3400-2700 cal BP, 'Lal-Lo 3000-1000 cal BP, Irigayen ~3500- 3000 cal BP and Nagsabaran ~4000-2600 cal BP (Snow *et al.* 1986; Hung 2005, 2008; Tsang 2007; Spriggs 2011a). Swete Kelly, however, is more inclined to date the emergence of red-slipped pottery in the Cagayan Valley to 3400 cal BP (Swete Kelly, personal communication, Jan. 2015 and in unpublished thesis 2008).

2.6. Were the Austronesians farmers?

The agriculture thought to have fuelled Austronesian expansion is proposed to be rice and millet farming (Bellwood 2005; Diamond and Bellwood 2003). There is currently very little archaeological evidence for rice and millet and it is almost invisible in areas where Neolithic Austronesians settled. Evidence of rice cultivation is found at few sites dated between 4000 and 2000 cal BP: two sites from Sarawak, Gua Sireh and Niah; Madai and Bukit Tengkorak in Sabah; and from one site in Luzon (Andarayan) (Bulbeck 2008). A small amount of *Oryza* sp. (wild or domesticated rice) has been found in Neolithic contexts dating to 3500 cal BP, in excavations at Kamassi and Minanga Sipakko in the Karama Valley, Sulawesi, but too few were found to establish whether rice was cultivated, or grew wild (Anggraeni *et al.* 2014:750; Anggraeni, 2012).

Bulbeck (2008:32) has argued that Austronesians appear to have switched very rapidly from grain cultivation to root and arboreal crops which dominate many Pacific agriculture systems. It has been argued by Denham and Donohue (2009) that the initial stages of domestication of sugarcane (*Saccharum robustus*) and bananas (*Musa* acuminate) were in New Guinea followed by movement westward to Southeast Asia where hybridisation took place. Roger Blench (2005) has shown that although a large number of words for economic trees could be reconstructed to a high level in Austronesian (eg banana and sugarcane) many species appear to have moved in the opposite direction to the Austronesian expansion with an origin in the Molucca Islands - Vanuatu region and tree crops distributed throughout a large part of the Austronesian zone prior to Austronesian expansion (Blench 2005:68).

2.7. Domesticated animals

The domestication of the pig (*Sus scrofa*) is a topic of significant debate for archaeologists in ISEA, with discussion of when, and how, Neolithic people switched from hunting wild pigs to husbandry of domestic pigs. This is a complicated issue considering the wide distribution of native suids in Asia, western Indonesia and Sulawesi. Early evidence of *Sus scrofa* is common, however, in Neolithic sites in Taiwan. Pigs are also found at Nagsabaran in the Cagayan Valley, where a pig premolar (although found in an *upper* Neolithic layer) is dated to 4500-4200 cal BP (Hung 2008; Bellwood 2011; Piper *et al.* 2009). Evidence of domesticated pigs is also found in basal layers at Kamassi and Minanga Sipakko in Sulawesi, dated to ~3500 cal BP (Anggraeni *et al.* 2014). *Sus celebensis* had been introduced from Sulawesi to Flores in the pre-Neolithic period and is found at Liang Bua from 8000 cal BP (Bulbeck 2008:35).

In studies of pig DNA (Larson *et al.* 2007; Dobney *et al.* 2008) the dispersal routes of human-introduced pigs becomes even more complex. *Sus scrofa* remains dated to 3500-3300 cal BP in the Molucca Islands and in the West Pacific at Lapita sites, and all those found elsewhere in Oceania, all have Pacific Clade haplotypes. The Pacific Clade haplotypes are absent in modern and ancient DNA samples from mainland China, Taiwan, the Philippines, Borneo and Sulawesi, suggesting that human dispersal out of Taiwan to the Pacific through the Philippines did not involve the movement of domesticated pigs. The pig found at Nagsabaran is also not from Taiwan (Piper, personal communication, Feb. 2015). The distribution of Pacific Clade pigs, identified in the study of Larson *et al.* (2007) indicate that they originated in East Asia, potentially in peninsular Southeast Asia, and were introduced to the Sunda Islands, the Moluccas and the New Guinea region, finally reaching islands in the Pacific with the Polynesian colonists (Larson *et al.* 2007:4837).

This is also consistent with recent mitochondrial DNA-research of the domesticated chicken that shows the predominant (77%) chicken mtDNA lineage in the Pacific is haplogroup D, a haplogroup which is absent in Taiwan. Haplogroup D most likely originates in Southeast Asia, and the dispersal of the Pacific chicken seems to have followed the same route as the Pacific Clade pig, and the domesticated dog (although the dog may have been present in ISEA before the Neolithic), which were most likely introduced to Indonesia via Mainland Southeast Asia (Miao *et al.* 2013; Oskarsson *et al.* 2011).

The Pacific rat (*Rattus exulans*) is the third most widely dispersed rat species, with a distribution from mainland Southeast Asia, throughout ISEA and across the Pacific. It is thought to have originated in ISEA or peninsular Southeast Asia, and does not appear in Near Oceania before the Holocene. The first *Rattus exulans* remains come from the earliest layers of Lapita settlements and are present in all archaeological sites associated with the Lapita culture and with the later Polynesian expansion (Matisoo-Smith and Robins 2004:9168*). Rattus exulans* is not found in any prehistoric context in Taiwan and hence could not have arrived from Taiwan with the first Austronesians. This implies rats came from elsewhere in ISEA or Southeast Asia, and were carried with the first Lapita settlers.

In their mtDNA study of *Rattus exulans*, Matisoo-Smith and Robins (2004) identify three distinct haplogroups: Haplogroups I, II and III. Haplogroup I consists solely of Southeast Asian samples from the Philippines, Borneo and Sulawesi, which suggests an interaction sphere within ISEA that has no relationship with Oceanic settlement. Haplogroup II consists of Southeast Asian and Near Oceanic samples, and could indicate an eastern route of dispersal from the Philippines into Wallacea and then to Oceania. The third group, Haplogroup III, represents Remote Oceania except for samples from Halmahera which appear in both Haplogroups II and III (Matisoo-Smith and Robins 2004:9168).

Another example of human-assisted introduction of fauna in the ISEA region is the cuscus (*Phalanger orientalis*). Instead of being transported west to east, it was introduced from New Guinea to Timor, and other parts of the south Maluku 10 000-8000 years BP (O'Connor 2006:83). It is found in New Ireland, Papua New Guinea, somewhere between 20 000 and 10 000 BP, and further into the Solomon Islands after 6000 BP (Spriggs 1998:55).

2.8. The Neolithic package in the Indo-Pacific region

The Austronesian expansion as described by Bellwood (2011) and others, proposes that agriculture resulted in demographic growth that prompted Taiwanese migrants, with a 'Neolithic package' of rice, domesticated pigs and dogs, red-slipped ceramic, polished stone adzes and other items, to colonise Island Southeast Asia at the expense of already existing hunter-gatherer societies. This is clearly a difficult event to confirm or deny with archaeological evidence. There is little doubt that Austronesian is a language group consisting of thousands of languages distributed in Southeast Asia, the Pacific and Madagascar which has an origin in Taiwan (Blust 1984/1985 2013; Donohue and Denham 2010). Clearly, Austronesian languages rapidly spread over a vast area but, was early language expansion propelled by agriculture? Blench (2014) has recently argued that "the Austronesian expansion was the consequence of a failed agricultural revolution and a reversion to opportunistic foraging".

A partial 'Neolithic package' arrived in the northern Philippines around 4000 BP, and certain items in it may have come from Taiwan, but recent archaeological research has failed to demonstrate that it contained a suite of domesticated animals such as pigs, chicken and dogs, or cereal crops such as rice or millet. Although some *Sus scrofa* remains are found at Nagsabaran, they do not appear to derive from Taiwan (Piper, personal communication, Feb. 2015), and do not occur in the same quantity as the remains of wild pigs (Amano *et al.* 2013). Instead, the subsistence economy from sites such as Nagsabaran and Lao-Lao seem to have consisted of foraging and hunting wild animals such as pigs and deer, together with shell-fish and fish. It appears that if Austronesian migrants brought grain cultivation and husbandry from their homeland they quickly switched to root and arboreal crops, hunting and foraging (Bulbeck 2008).

It has been proposed that the first farmers leaving Taiwan on their southbound colonisation route carried the above-mentioned domestic animals and cereal crops, together with red-slipped ceramics with specific rim forms and body shapes, pottery spindle whorls, discs of clay, stone bark cloth beaters, polished stone adzes, net sinkers, and jade ornaments (the ear ornaments known as lingling-o) to the Batanes and northern Luzon around 4000 BP (Bellwood 2011:368; Bulbeck 2008). All of these features are found in different sites in northern Luzon, although rice remains are found as an inclusion in pottery from Andarayan and dated to ~3400 cal BP (Snow *et al.* 1986). This is within the same timeframe as Swete Kelly (2015a) suggests for the introduction of a red-slipped ceramic tradition to northern Luzon.

From Luzon, it appears that only a few of these items travelled further than the Philippines. The pottery spindle whorls and jade lingling-o all stayed in the Philippines until the 'metal' age when jade valuables were distributed as far as Sarawak, coastal Vietnam, Cambodia and southern Thailand (Bulbeck 2008:42). Stone bark cloth beaters are found outside Luzon at Niah in Sarawak, and Kalumpang in Sulawesi, but are not found in the Bismarck Archipelago or further out in Remote Oceania. Polished stone adzes extend across a very large area of Taiwan, ISEA and across the Pacific during the Neolithic. It is not clear if Taiwan was the only place where early polished stone adzes were made as there are polished adzes in mainland Southeast Asia. A polished stone adze associated with a burial dated approximately to 4600 cal BP at Duyong Cave on Palawan in the Philippines (Fox:1970) in a pre-ceramic context suggests that polished adzes were widespread and that there were other sources than Taiwan for this artefact category (Bulbeck:2008).

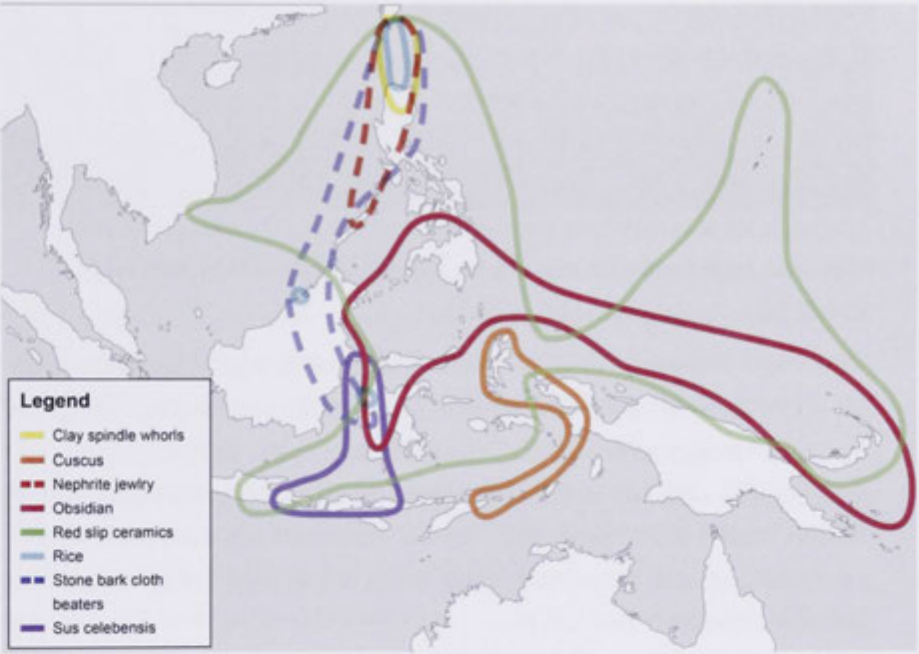


Figure 3. Distribution of different items belonging to the Neolithic package (After Bulbeck 2008).

2.9. Pottery

The presence of pottery, especially red-slipped ware, has become a proxy for both the presence of Austronesian-language speakers and the Neolithic cultural traits that they are thought to have possessed (Swete Kelly 2008:28).

The earliest red-slipped pottery is found in Taiwan from 4200 cal BP at Chaolaiqiao on the southeast coast of Taiwan. It appears in the Cagayan Valley in northern Luzon at sites such as Nagsabaran at 3700 cal BP, and possibly as early as 4000 cal BP (Hung

2008; Hung *et al.* 2011). Swete Kelly (2008) argues against such an early date for the appearance of red-slipped pottery in northern Luzon. The best-dated site in northern Philippines is Nagsabaran, but even here there are serious questions about site age that are discussed in Chapter 8 and Chapter 10.

If northern Luzon was the second dispersal point for pottery, then there appears to have been a rapid spread of red-slipped ceramics that is almost instantaneous in terms of archaeological dating. On a north-south axis, red-slipped ceramics spread from about 3700 cal BP at Nagsabaran in the Philippines (Hung *et al.* 2011) to Pulau Ay in the Banda Islands by 3500-3400 cal BP (Peter Lape, personal communication, April 2014), a linear distance of some 2700 kilometres in ~200 years. On an east-west axis, red-slipped ceramics appear at several sites in the Bismarck Archipelago around 3470-3250 cal BP (Specht *et al.* 2013; Denham *et al.* 2012), and at sites like Unai Bapot and Achuago in the Mariana Islands from about 3200-3100 cal BP (Winter *et al.* 2012: Clark *et al.* 2010; Clark *et al.* in prep.), but possibly as early as 3600-3500 cal BP (Carson 2014; Carson and Kurashina 2012).

In the west, red-slipped ceramics are dated to 3300 cal BP at Bukit Tengkorak in Sabah and to 3500 cal BP at Kamassi and Minanga Sipakko in southwest Sulawesi (Anggraeni *et al.* 2014; Simanjuntak *et al.* 2008). From Bukit Tengkorak to the Bismarck Archipelago the distance is around 3600 kilometres. A piece of Talasea (Kutau/Bao) obsidian, found at Bukit Tengkorak and dated to 3300 cal BP, illustrates that at least some cultural material, and possibly people, moved vast distances during this period (Bellwood 1989, 2011; Chia 2003).

If a polygon is outlined using the location of the archaeological sites mentioned above (Figure 4) to locate the boundary (Nagsabaran in the north, Marianas in the east, Bismarck in the south, the Banda Islands in the southwest, and Bukit Tengkorak in the north) then the area with red-slipped pottery is around 10 million square kilometres, although two thirds of it is ocean.

Figure 4. Area of early red-slipped pottery distribution.

Since the time of Childe (1929), ceramics have been central to hypotheses about human migration and interaction, particularly in discussion of the Neolithic in Europe as with the *Funnel Beaker culture*, (abbreviated to *TRB* from *Trichterbecherkultur*) and the *Pitted Ware culture* (Mallory 1989; Renfrew 1987). The similarity in ceramics, especially red-slipped ceramics found in archaeological contexts across ISEA and in Near and Remote Oceania, has similarly been central to the formation of hypotheses of prehistoric interaction and migration. Red-slipped ceramics have also been linked to agriculture and the presence of Austronesian language-speaking peoples (Swete Kelly 2015a).

2.10. Red-slipped pottery and the Austronesian expansion

The presence of red-slipped ceramics at different archaeological sites in ISEA and the Pacific has led many researchers to see relationships between distant pottery-making communities. Many studies describe the pottery from one or more sites in ISEA and the Pacific, but very few have focused on understanding pottery relationships in detail over a large area.

In the 'Out-Of-Taiwan' model proposed by Bellwood and other researchers, Taiwan was colonised from south-eastern China by proto-Austronesian speakers around 5500 years ago. These colonisers brought with them a new set of material culture and the earlier Changbian culture was assimilated or replaced. The new material culture is known as Tapenkeng culture (TPK). By 4500-4000 BP, an expansion occurred beyond Taiwan and the red-slipped ceramics tradition was introduced by Neolithic colonists to areas of ISEA where there had previously been no evidence of earlier pottery or farming. According to Bellwood's model, these pottery-carrying agricultural populations moved southward through the Batanes Islands into northern Luzon where a break of a few hundred years occurred and then a rapid dispersal took place. As mentioned previously, one group dispersed through the southern Philippines, Kalimantan, Sulawesi and on to Java, Sumatra, the Malay Peninsula and to southern Vietnam (where Western-Malayo-Polynesian languages developed). Another group is thought to have sailed straight to Western Micronesia and the Mariana Islands and later to Melanesia. A third group went through the Moluccas to reach the Lesser Sunda Islands (where Central Malayo-Polynesian languages developed) and through Halmahera to Melanesia and Polynesia (which resulted in the development of Oceanic languages).

The model heavily relies on the evidence for the spread of Austronesian languages in ISEA as presented by Blust (1984-1985; 1995) and archaeological evidence, primarily pottery. The pottery is characterised by simple vessel forms, sometimes with perforated ring-feet, with plain or red-slipped surfaces, and carrying rare incised or stamped decoration (Bellwood, 2005).

Although there is no convincing method to correlate red-slip pottery with a prehistoric language, the timing of the Austronesian language expansion and the emergence of red-slipped pottery in ISEA appear to overlap (Donohue, personal communication Feb. 2015). However, evidence that Austronesian language spread was driven by an agricultural revolution is as yet very limited, with little or no evidence for early crop cultivation in ISEA. Sites where presumed Neolithic material culture is found lack archaeological evidence for crop cultivation and pottery has become the main cited indicator for both agriculture and language spread (Swete Kelly 2015a). Without a strong link between pottery and rice/ millet cultivation, the theoretical basis of an Early Agriculture Dispersal Hypothesis must be treated cautiously.

Recent research, for instance, suggests that there are several archaeological sites around the world where pottery was developed in a non-agricultural context. Pottery is dated from 15 000 to 10 000 cal BP in China (Boaretto *et al.* 2009), in Japan from about 15

000 to 11 800 cal BP (Craig *et al.* 2013) and 5500-5000 cal BP in the Brazilian Amazonas (Roosevelt 1995). In these and other instances, pottery predates the adoption of an agricultural subsistence base. Pottery and farming are not co-dependent technologies and there should be no *a priori* assumption linking the two. Therefore, it cannot be taken for granted that the movement of pottery in ISEA is congruent with the movement of farmers and agriculture (Swete Kelly 2015a:4). Conversely, the presence of pottery is not proof of sedentarism and agricultural subsistence, as is commonly asserted in the case of early archaeological sites with red-slipped pottery. In ISEA, early pottery often includes relatively small containers that are compatible with a nomadic or semi-nomadic lifestyle (de Saulieu and Testart 2015).

Nevertheless, the presence of pottery has become the single most important indicator of the ISEA Neolithic and Austronesian language spread. Matthew Spriggs argues that dialects of Proto-Malayo-Polynesian (PMP) were spoken everywhere from the Philippines to eastern Borneo, Sulawesi and south to East Timor by 3800 cal BP, and spread with the first pottery-using cultures. A few centuries years later, Eastern-Malayo-Polynesian speakers reached northern Maluku and by 3350-3300 cal BP had sailed to the Bismarck Archipelago where Proto-Oceanic developed (Spriggs 2011:511a). For the Mariana Islands, Hung *et al.* (2011) have proposed that the first settlers arrived from the northern Philippines by 3500 cal BP, or slightly earlier. This early Neolithic expansion from northern Luzon is based on similarities in pottery assemblages between early sites in the Mariana Islands and Nagsabaran. Furthermore, Hung *et al.* argue that the most likely source of Chamorro is northern Philippines from linguistic data (Hung *et al.* 2011:923).

Several models of migration in ISEA are based on the similarity of a small number of attributes in different ceramic assemblages. The models that use such data are often less definitive than they are touted to be (Swete Kelly & Winter 2015), and very seldom are similarities assessed from a structured comparison of material from different sites, but rather from impressionistic assessment. One outcome is that assemblage diversity and difference is neglected in favour of a small number of attributes, often generic, that are identified as being similar among assemblages (Szabo and O'Connor 2004).

Spriggs, for example, notes that: "A 4000 BP pottery assemblages in Luzon may not be directly comparable to a 3500 BP assemblage in Sulawesi or the Marianas, or a 3000 BP assemblage in Sabah. When they are very similar that is all to the good, but if they are not then we should not be too surprised." (2011a:521). Spriggs may be right, but on the other hand he also writes that after 200 years of dispersal, dialects of PMP were spoken over a vast area stretching from Philippines in the north to East Timor in the south (3000 kilometres apart) spreading with the first pottery-using cultures. What if early pottery assemblages of the same age that are supposed to have been spread by the same dispersal are different? Should we be surprised and perhaps query the model? Considering the short period of time Spriggs proposes for the spread of pottery and language, one could reasonably expect a much more similar material culture than is actually reported from the various sites, at least in terms of the pottery.

This is the case for Lapita pottery, for example. The earliest Lapita pottery in the Bismarck Archipelago is very similar to later Lapita pottery found in Vanuatu, although there might be a 200-300-year gap and some 2000 kilometres between the two places (Bedford, personal communication Feb. 2015). The same is also true for the earliest phase of the Neolithic in north-central Europe and southern Scandinavia, where the Funnel Beaker culture (6300-4800 cal BP) occurs over a wide area. This homogenous pottery tradition has been explained by Gill in the following terms: "Stability in the choice of vessel forms and decorations show that the early Neolithic Funnel Beaker pottery design has been very important in the parts of Europe where it has been made. Innovation or new-thinking has not been considered important, but rather norm and tradition. The potters have not improvised, but have been working within the borders of a traditional set of themes. The production of Funnel Beaker pottery can be looked upon as a way of socialising and where cultural values and knowledge have been reproduced by generation to generation" (Gill. 2003:74 translation by the current author).

Nigel Barley pointed out the same thing in his book *Smashing Pots* (1994) where anthropological studies in Africa showed that innovations in pottery-making were extremely rare and that divergence from the accepted way of making a pot was looked upon as a defect or mistake. In the ceramic-making cultures investigated by Barley, ceramics were considered as important as oral history/tradition (Barley 1994:115).

2.11. How similar is similar?

Several archaeological models draw links between ceramics assemblages from different sites from different regions in ISEA and the Pacific. Some ceramics are thought to be very similar and to have derived from a particular place. This is the case argued for red-slipped pottery in the northern Philippines that is said to come from the east coast of Taiwan through the Batanes Islands in the Luzon/Formosa Strait, and circle stamping, a trait specific to Batanes Island ceramics and thought to have also come from Taiwan (Bellwood and Dizon 2014; Bellwood 2011; Hung 2005; Hung 2008; Carson and Hung 2014). Further links between red-slipped pottery from eastern Taiwan, the Batanes Islands and northern Philippines, especially archaeological sites in the Cagayan Valley, have been made with ceramics from the Neolithic sites of Minanga Sipakko and Kamassi in the Karama Valley, Sulawesi where early vessels are red-slipped and have tall and/or concave rims. Some of the early Karama Valley ceramic sherds are incised or have stamped decoration. This led the excavators to conclude that the Karama Valley ceramics are: "so closely paralleled in contemporary pottery sequences from eastern Taiwan, the Batanes Islands, northern Luzon and eastern Sabah that sheer coincidence is not acceptable as an explanation" (Anggraeni *et al.* 2014:750). The Cagayan Valley and especially Nagsabaran has also recently been the focus of research articles that link the first colonists of the Mariana Islands to northern Luzon and the development of Lapita culture in the Bismarck Archipelago, based on similarities seen in the punctate and dentate-stamped decoration (Hung *et al.* 2011; Carson and Kurashina 2012; Carson *et al.* 2013).

2.11.1. Defining 'similar'

What are the criteria when comparing different ceramic assemblages? Most often, studies of ISEA ceramics focus on decorative attributes and vessel forms which are standard in other parts of the world. Very few comparative analyses of ceramics from different sites in ISEA have expanded their studies to attributes other than colour, vessel form and decoration. Although several thorough studies (e.g. petrographic/tool use/clay sourcing) of ceramic assemblages from single or multiple sites on the same island, or islands close by each other in the Pacific have been done, the same is not true for ISEA (Summerhayes 2000, 2009; Clark and Wright 2005; Bedford 2006). Important exceptions are Soheim's 1952 pottery study and Swete Kelly's 2008 PhD thesis, *Prehistoric Social Interaction and the Evidence of Pottery in the northern Philippines*, which examined all the radiocarbon dates available for Neolithic sites in northern Luzon. Furthermore, Swete Kelly carried out extensive studies of ceramic assemblages from two sites on the east coast of Taiwan (Huakanshan and Peinan), seven sites in the Batanes islands (Torongan Cave and Anaro on Itbayat Island, Sunget Top Terrace, Sunget Main Terrace, Naidi, Payaman and Tayid on Batan Island) and three sites in northern Luzon (Dumbrique, Irigayan and Dimolit). Swete Kelly's pottery analysis included the study of primary attributes (shape, size, vessel orientation etc.), surface modification/surface alteration (décor), use wear, firing temperature, petrographic characterisation with SEM-ESXA and XRD, and fifty sherd samples analysed in thin section by William Dickinson at the University of Arizona.

The proposed ceramic links between Taiwan-Batanes Islands-northern Luzon-Karama Valley-Mariana Islands and Island Melanesia/western Polynesia (Anggraeni *et al.* 2014; Carson *et al.* 2013; Bellwood 2011; Hung 2008), are based on vessel forms and specific kinds of circle-and punctate-stamped decoration, and lack vital information about manufacturing, petrographic and mineralogical characterisation of clay and temper. Nevertheless, some decorated ceramics from Karama Valley are said to: "parallel almost precisely to sherds from Magapit" (Cagayan Valley), some "concave rims are identical to rims from Nagsabaran and Magapit" and "remarkably similar to plain red-slipped pottery from Chaolaiqiao (Taiwan) and Reranum" (Batanes Islands) (Anggraeni *et al.* 2014:751-752). Likewise, decorated ceramics from early sites in the Mariana Islands compared with early decorated ceramic from Nagsabaran are said to be "extremely similar" (Hung *et al.* 2011:916) and "virtually identical" (Carson *et al.* 2013:21). It is important to note that less than 1% of the early ceramic assemblages from the Mariana Islands and Nagsabaran are decorated with circle and punctate-stamped décor. The rest of the ceramic assemblages, a little more than 99 percent of undecorated ceramics, are important for making a wider comparison and determining at the assemblage level whether pottery from different sites, sometimes thousands of kilometres distant, are in fact 'virtually identical' or 'extremely similar'. The attributes that are described as very important in declaring similarity between ceramics from the Karama Valley and Taiwan/northern Luzon area, are tall and concave rims. Are these attributes, for instance, present in the earliest assemblages from the Mariana Islands, and if they are not, what does it mean for a hypothesis of a widespread and unified early pottery culture?

The distance from northern Luzon to the Karama Valley is approximately the same as the distance to the Mariana Islands (~2200 kilometres), with the obvious difference being that between northern Luzon and the Marianas it is mostly open sea, whereas several islands lie *en route* to the Karama Valley in Sulawesi. If an important aspect of the ceramic tradition (tall concave rims) could remain intact during migration through the Sulu Sea and Celebes Sea and was established in an already populated zone near the Makassar Strait, it seems reasonable to assume that the same should be true of the first ceramic assemblages to arrive with people on the previously uninhabited Mariana Islands.

The issue with simple comparisons such as the ones above is that rather than being based on thorough analysis of multiple ceramic variables describing shape, fabric, paste, chemical and mineralogical features, petrofabrics, textures and so on, in order to group, classify and categorise pottery vessels with specific characteristics to an assemblage, the interpretation is mostly generated from a theoretical framework. In this case the 'Out-Of-Taiwan' model, where all ceramics with certain attributes found south of Taiwan are associated with an expansion of Austronesian-speaking agriculturalists from Taiwan or from a secondary staging area in northern Luzon. When ceramics 2200 kilometres away appear to fit with the model, as in the Karama Valley, then a vast Austronesian migration is asserted. Troublingly, though, when they do not fit the model perfectly, as with the Marianas, where perhaps less than 1% of the hundreds of thousands of sherds excavated fit the model, it's explained as "localised modifications expected in a classic founder-effect scenario" (Hung *et al.* 2012:911).

The 'founder effect scenario' is also one of the hypothesised ideas put forward by Carson *et al.* (2013) to explain why the more elaborate Lapita design system developed as an offspring from the Nagsabaran/Mariana Islands circle and punctate-stamped décor. Carson *et al.* (2013:30) write: "Founder-effect transformation must be recognised as more than a monotonic diminishing of sub-sets, with each successive offspring group progressively further separated from its larger parent population. Along with the bottle-neck loss of certain ancestral traits, each sub-set gains new characters of integrative or innovated traits. This outcome is most noticeable in the case of Lapita, wherein a rather limited inherited core decorative system was impressively elaborated". In other words, both similarity *and* dissimilarity in early ceramics from ISEA and the Pacific are interpreted as supporting the Out-Of-Taiwan model.

Archaeological models like the ones above, especially the Philippine-Mariana-Lapita link, when only one archaeological material variable (and only a small part of it) is considered, run the considerable risk of generating simplistic explanations about human migration and interaction.

An explicit and replicable method for comparing ceramics from different sites separated by time and space to examine migration is through an archaeometric study. Archaeometry encompasses a group of analytical techniques applied to the study of material culture with the aim of obtaining quantitatively and qualitatively rich and diverse groups of data (Santacreu 2014:2). Quantitative data obtained from scientific and technological ceramic studies can be explored with statistics to establish pottery variation. The potential variability within ceramic assemblages is crucial for developing models of migration based on the material culture of the migrants. This approach is based on in-depth study of prehistoric records of migration from the physical residue left behind by the migrants themselves, as opposed to using inferences from linguistics and genetics, or assumptions about migration applied to archaeological data. .

2.12. Chaîne opératoire

Pottery is a fictile material that is more or less adapted to perform a particular function, but the principles governing function and the features applied to a ceramic object are determined by cultural factors (Santacreu 2014:190). The concept of *chaîne opératoire* sees all technological choices regarding the material and techniques, as well as the actions involved in the pottery production process as part of an operational sequence. The concept involves the choice of raw material selected, the pottery building technique, the choice of decoration, the firing methods, and use of the final product. The choice of raw materials in pottery and the type of manufacturing technique are particularly useful variables since they provide reliable data about the potter's *savoir faire* (know-how).

The notion of *chaîne opératoire* is an appropriate strategy to compare technological choices made by potters to establish whether there are existing relationships between material and technique within a ceramic assemblage or between assemblages from different sites.

Chaîne opératoires are considered to be representative and characteristic of a particular society where continuous repetition of technical choices and choice of raw material shows the potter's specific *savoir faire*. Technology is always associated with some knowledge, which allows a relationship to be established between specific *chaîne opératoires* and their final product (Santacreu 2014; Lemonnier 1986).

This thesis uses aspects of the *chaîne opératoire* concept in the analysis of pottery from the Unai Bapot site on Saipan Island in the Mariana Islands to establish the manufacturing process used by migrants to make the first ceramics in the Marianas. The approach of *chaîne opératoire* is further used as a methodological tool, to establish whether there is a relationship between pottery from Unai Bapot and ceramics from four different Neolithic sites in the Indo-Pacific region: Chaolaiqiao, Taiwan; Nagsabaran, Philippines; Ulong, Palau and Ambitle, Bismarck Archipelago.

3. Micronesia

3.1. Geographical constructs

Micronesia is a large group of more than two thousand small islands scattered across the Western Pacific Ocean, lying predominately north of the equator. The word 'Micronesia', meaning 'small islands', was first coined by the French travel writer Grégoire Louis Domeny de Rienzi in 1831. The Islands cluster into four archipelagos: the Mariana Islands, Carolines Islands with Yap and Palau in the very western end, Marshall Islands and Gilbert Islands; and isolated islands as far as Wake Island in the north and Nauru Island in the south. The four archipelagos and individual islands equal a total land mass of ~2700 square kilometres scattered within ~7.4 million square kilometres of open sea (Craib 1983, Moore 1983:6). The islands of Micronesia vary in size and formation, from very small low-lying coral atolls like the islets of Lamotrek Atoll with a combined land area of 0.85 square kilometres; to large higher islands such as Guam, the largest island in the group, with a land area of ~554 square kilometres (Rainbird 2004:34). Islands vary in elevation from 1m to 1000 m. The four distinctive archipelagos are the result of long-term geological processes that have submerged mountains or pushed coral reefs above sea level. The Mariana Islands are the furthest northwest of these archipelagos, located in a north-south arc, situated on the edge of the Pacific 'Rim of Fire', a geological feature formed where the Pacific Plate pushes underneath the Philippine Plate. This is a geologically unstable area and all islands in the archipelago are prone to earthquakes. Geologically, the Mariana Islands are made up of a combination of andesitic and basaltic igneous rock. South of the Mariana Islands lies the east-west chain of the Caroline Islands, with the high islands of Palau Archipelago and Yap Island at its western end. Palau and Yap also formed as a result of subduction zone activity and are also composed of andesitic lavas, basaltic metamorphic rocks and sedimentary limestones (Moore 1983, Rainbird 2004:39-40). To the east of the Yap Trench the island-forming geology is purely volcanic. The Andesite Line, which encircles the Pacific, marks the differences in the chemical composition between the igneous rocks of the high islands formed on the Pacific basin floor and those formed on marginal land of the submerged continental shelves (Moore 1983:6; Rainbird 2004:40). To the east of the Carolines are the Marshall Islands, formed by two archipelagos of low-lying islands. The eastern island chain is called the Ratak Islands, the 'Islands of the Sunrise'. To the west is the island group Ralik, the 'Islands of the

Sunset'. To the south of the Marshall Islands are the low-lying Gilbert Islands which are part of the Republic of Kiribati. Four islands, all located south of the Caroline Islands, fall outside of these geographically distinct groups: Banaba Island, Nauru Island, Nukuoro Island and Kapingamarangi Island. The first two are upraised limestone islands, while the latter two are coral atolls. South-west of the Palau Archipelago lie the small islands of the Southwest Island group. Together, these islands: The Marianas, Carolines, Marshalls, Gilberts, Southwest Islands and the four individual islands comprise the geographical area known as Micronesia (Rainbird 2004:40).

Figure 5. Map of Micronesia divided into Western, Central and Eastern zones (After Clark 2010).

3.2. Micronesia the cultural area

The French Naval Captain Dumont d'Urville is often credited with having coined the terms Melanesia, Polynesia and Micronesia in the 19th century, but rather than coining the names, he developed pre-existing labels. 'Micronesia' was actually first mentioned by Grégoire-Louis Domeny de Rienzi, less than a month before Dumont d'Urville used it the first time (Clark 2003:158). Dumont d'Urville noted: "Northern Oceania is the second division, and it comprises the entire second group of the copper-skinned race. I shall call this area Micronesia, as it contains only very small islands, the largest being Guam in the Marianas and Babel Thuap [Babeldaob] in the Palau Islands. Except for the ending, the name Micronesia is the same as that suggested by Mr de Rienzi" (Clark 2003).

Dumont d'Urville's Micronesia consisted of the Kingsmill Group, the Gilbert Islands, the Marshall Islands (or Radak and Ralik), the Carolinas, the Marianas, the Palau Islands, and finally the uninhabited islands between Japan and the Hawaiian Islands. He also noted that the small islands of Micronesia did not have a homogeneous population as did Polynesia, but he observed 'general' racial similarities that perhaps indicated a common ancestry. D'Urville also believed that the Micronesians were related to the people of the Philippines, and he proposed that the original homeland of the Micronesian people must have been the islands of Luzon or Mindanao in the Philippines. d'Urville thought that the migrations of the first people to arrive in Micronesia were small in scale, and took place after a major human migration from the west of ISEA into the Pacific that resulted in the settlement of Polynesia (Clark 2003).

Peter Buck (1938) suggested that early Polynesians most likely came from Micronesia because they shared more physical similarities with them, than with the Melanesians. The racial status of Micronesians has always been uncertain because the bio-cultural definition of 'Micronesian' has been ill-defined, and the area itself is best described as a residual category of islands and a people that do not comfortably fit as being either Polynesian or Melanesian (Clark 2010; Rainbird 2003). It is simpler to define Micronesia as a geographical area than through the culture and history of its inhabitants, since Micronesian history is probably a complicated product of repeated human arrivals from different areas of ISEA and the West Pacific, in addition to Polynesia (Clark 2003; Rainbird 2003).

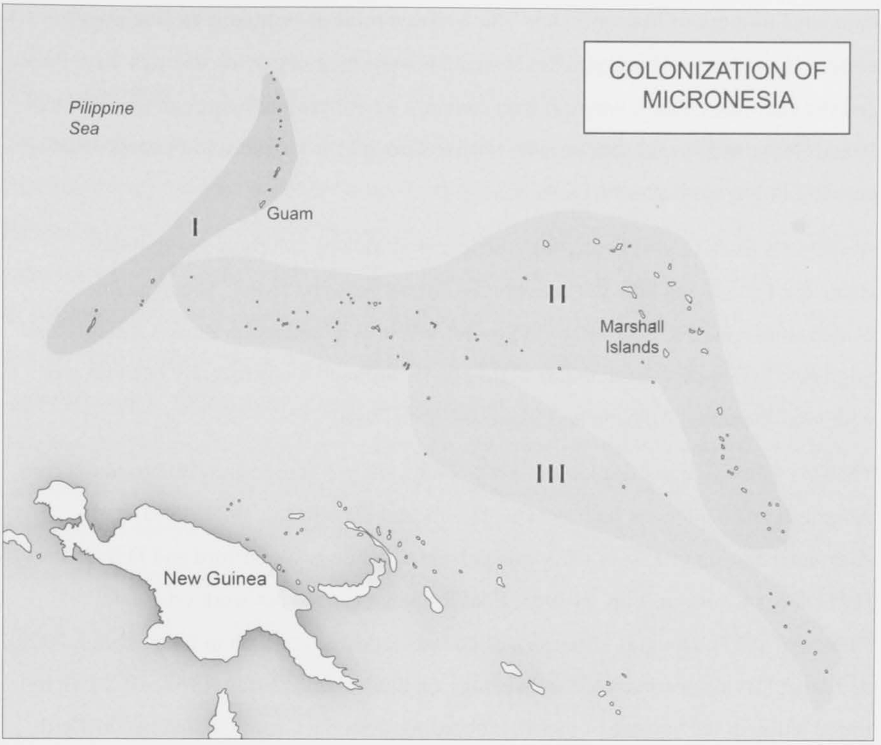


Figure 6. The colonisation of Micronesia divided in to three phases (Phase 1 = 1300-1000 BC, Phase 2 = 0 AD, Phase 3 = 500-1000 AD). (Modified after Clark 2010).

3.3. Micronesia from an archaeological perspective

Archaeology in the tropical Pacific is a relatively young discipline dating from around the 1950s. There has been a massive increase in the archaeology since the 1950s and 1960s when researchers began to realise that Pacific Islands possessed deep archaeological records, which could be described and understood by new method of radiocarbon dating and conventional excavation methods (Kirch 1997:8).

When Peter Buck (Te Rangi Hiroa), the Maori Director of the Bishop Museum wrote his best selling monograph *Vikings of the Pacific* (1938), the archaeology of Micronesia was poorly understood. Most information outside Japanese-held islands came from Hans Hornbostel's notes, artefacts and human remains collected in the 1920s from the Mariana Islands (Rainbird 2004:66). Buck hypothesised that Polynesia was colonised by people using a northern Micronesian route to settle Polynesia. His evidence for such a hypothesis relied on the racial characteristics, linguistics and mythology of Polynesia compared to those of Micronesians. The northern route as proposed by Buck began in eastern Indonesia and bypassed the Mariana Islands by going south through Yap, Palau and the Caroline Islands, where it branched into a northern route through the Marshall Islands towards Hawaii, and a southern route through the Gilbert and Phoenix Islands entering Polynesia just north of Samoa.

At the time Buck (1938) wrote, the evidence of a Melanesian route through the Bismarck Islands and into Western Polynesia had yet to be found. The available evidence increased rapidly after the Second World War and made Buck's Micronesian migration hypothesis obsolete (Rainbird 2004), although it has recently been revived with modifications (Addison and Matisoo-Smith 2010).

The first significant archaeological work conducted in Micronesia was carried out by American archaeologists such as Hans Hornbostel (Thompson 1932; 1945) and Alexander Spoehr (1957) in the Mariana Islands, while E.W. Gifford and D.S Gifford (1959) began work on Yap. In 1965, Fred Reinman carried out work on Guam (Reinman 1977), Douglas Osborne carried out extensive research in Palau (1966, 1979), and Janet Davidson conducted archaeology on the Nukuoro atolls (1967; 1971). In the introduction to the volume of papers proceeding from the Guam Conference in 1990, Rosalind Hunter-Anderson and Michael Graves (1990) noted that only 30 archaeological projects had been conducted in Micronesia since 1970. However ten years later by 2000, another 300 archaeological projects had been started or completed (Rainbird 2004:67).

The exponential rise in archaeological projects has continued and by May 2009, 470 projects had been completed on Guam alone, according to the Historical Preservation Office. Many projects were the result of salvage or development associated with tourist and military projects, but a number of investigations have been conducted for research purposes, as at Ritidian, Unai Bapot, and the House of Taga (Butler 1994, 1995; Carson 2008, 2010, 2011, 2012a, 2012b; Carson and Kurashina 2012; Clark *et al.* 2010; Craib 1999; Marck 1978; Moore *et al.* 1992; Winter *et al.* 2012).[1]

1 This represents only a selection of the available publications.

4. The Mariana Islands

4.1. Geology

The Mariana Islands consist of 15 Pacific islands dotted in a north-south arc at the junction of two tectonic plates between 13°N and 21°N latitude approximately 2400 kilometres east of Luzon in the Philippines (Russell 1998:1; Butler 1995:5). The islands occur in the most northern part of Micronesia just west of the Mariana Trench, the deepest marine trough in the world. The geology of the islands falls into two distinct groups. The northern group of nine islands, Farralon de Pajaros, Maug, Asunción, Agrigan, Pagan, Alamagan, Guguan, Sariguan and Anatahan, are relatively young volcanic peaks, some of which are still active. The southern six islands of Guam, Rota, Auguiguan, Tinian, Saipan and Farallon de Medinilla are made up of older upthrust platforms of marine limestone that formed around submarine volcanic cores that are dated to the late Eocene (Butler 1995:5, Russell 1998:5).

Figure 7. Map of the Mariana Islands.

The total area of the archipelago is ~1020 square kilometres. The southern islands, with the exception of Farallon de Medinilla, are relatively flat with fertile soils (Russell 1998:5). Three of the southern islands, Guam, Tinian and Saipan, have natural lagoons protected by reefs, primarily on their western coasts. The southern islands, except for Guam, lack fresh water sources Where there is fresh water, it occurs as a result of rainwater percolating through the limestone formations where it floats in lenses on top of denser salt water. The salt lakes are residual in the upthrust marine limestone platforms (Russell 1998). With a few exceptions, the nine northern islands are mountainous, lacking any protected reefs and beaches. They too have little fresh water.

Saipan is the northernmost island of the southern group and the second largest island in the Marianas. At 122.9 square kilometres, it is one-fourth the size of Guam. It is a narrow island 23 kilometres long and 10.7 kilometres wide at the Garapan-Hakmang axis, but most of the island is less than 4 kilometres wide. Geologically, Saipan is constructed of a series of platforms of marine limestone encircling a volcanic core of Eocene age (Butler 1995:5). The southern part of Saipan consists of broad and level limestone platforms. The central and northern parts of the island are dominated by a mountain range of axial uplands of volcanic and metamorphic origin. Mount Takpochao is Saipan's highest mountain with a height of 466m.

Saipan's east, southeast and west coasts are very different. The east coast is very rocky and dominated by limestone cliffs with few beaches with only a few narrow fringing reefs. On the southeast coast is a large bay, known as Laulau Bay or Magicienne Bay. It is a deep embayment, but as it is open to easterly winds it does not provide a protected anchorage. On Saipan's west coast are large areas of sandy beach fringed by extensive barrier reefs that form the largest lagoon complex in the Mariana Islands. The barrier reef is approximately 17km long, extending from San Roque in the north to Agingan Point in the south. The lagoon system ranges in width of 375 m to more than 700 m (Butler 1995).

4.2. Climate

The Mariana Islands' climate is even. There are two seasons: the dry season from January-May, and the wet season between June and December. There is minor seasonal variation in temperature. Daytime temperatures range between mid-upper 30's and night time temperatures range between the mid-uppers 20's, degrees Celsius. Average annual rainfall is ~250 cm. Rainfall varies between the wet and dry season, with light rainfall and strong easterly to northeasterly trade winds dominating the dry season. In the wet season, the weather is more unstable, with frequent tropical storms with heavy rains. Two thirds of the annual rainfall falls during the wet season and typhoons occasionally occur (Russell 1998:7). They generally build up to the east of the Marianas and slowly move westward, increasing in strength. The typhoons vary in intensity with winds between 118 kilometres per hour up to super typhoons with winds of 241 kilometres per hour. Typhoons are devastating when they approach the islands and high winds associated with these systems destroy human structures. Rain and storm waves contribute to erosion and can reconfigure the coastal landscape. Despite its high rainfall, Saipan has little standing surface water; marine limestones are very porous and absorb rainwater leaving little runoff available for humans and fauna. Some fresh water accumulates via surface drainage in non-limestone areas, but on the steep slopes of the mountainous regions, runoff is rapid and pooling is limited. While fresh water availability today is poor, Saipan would prehistorically have had more fresh water than a number of other islands in the archipelago. The access to water on the western coastal plain was very poor, but this area was undoubtedly the most populous in prehistoric times (Butler 1995:9).

4.3. Flora and fauna in the northern Marianas (Saipan)

Saipan's vegetation has been very heavily disturbed by agriculture, construction and the massive impact of military operations during World War II. It is therefore difficult to estimate the extent and type of vegetation in prehistoric times. Humans have been modifying the vegetation on Saipan for at least the last 3000 years and possibly longer, according to some palaeoenvironmental results (discussed below). Initially, human impacts on the environment would probably have occurred in coastal areas. Some forest clearing would have followed the introduction of economically important plants. Later in prehistory the human impact on the environment would have increased as settlement moved inland. The greatest impact on vegetation is associated with the Japanese colonial era. Large sugarcane plantations and population increase resulted in the eradication of Saipan's native forests. In the final years of World War II, especially during waves of invasion in 1944, many remnant patches of forest were destroyed. A number of aggressive plants were also introduced to Saipan by the Japanese occupation forces. Two of these have now overtaken a large proportion of the island. The tangantangan (*Leucaena glauca*), which is particularly dominant, and the Korean koa (*Acacia confusa*). Prior to the introduction of these two species there were four major types of flora on Saipan: coastal (strand vegetation), limestone forest vegetation, savannah, and wetlands. The most common species of the strand vegetation were *Hernandia sonora, Pisonia grandis* and *Thespesia sp.* Coconut would also have been present together with *Casuarina sp.* (Athens and Ward 1999:192). Vegetation would have been a mixed forest depending on moisture variability. In areas of high moisture, banyan (*Ficus* sp.) and breadfruit (*Artocarpus* sp.) would have dominated. Other major species would have been *Intsia* sp., *Premna* sp., *Pisonia* sp. and *Hernandia* sp.. A variety of shrubs and vines such as *Guamia* sp., *Maytenus* sp., *Cycas* sp., *Genistoma* sp. and *Piper* sp., together with orchids and ferns would have been present (Butler 1995:10).

The extent of grassland or savannah vegetation at the time of first colonisation of the island is uncertain. These vegetation types were certainly present at the time of European contact, however researchers disagree as to whether they were caused by anthropogenic activity or a natural occurrence. Savannahs are principally associated with volcanic soils and upland formations, where the dominant plants are swordgrass (*Mischantus floridulus*), ferns (e.g. *Gleichenia sp.*) and scattered *Pandanus* trees.

On the coastal plains of Saipan there are a series of wetlands. Reed marshes are the most common with the tropical reed (*Phragmites karka*) the main species. These areas contain heavy water-saturated soils and hold standing water during rainy periods. A small brackish-water lake, Lake Susupe, lies on the coastal plain behind Chalan Kanoa. Currently there is only one small area of mangrove habitat on Saipan. Located at the mouth of a small freshwater stream between Garapan and Tanapag, it is dominated by species such as *Bruguiera sp.* , *Gymnorhiza* sp., *Heritiera littoralis* sp. and *Xylocarpus moluccensi* sp.; the typical mangrove *Rhizophora* sp. is not present (Butler 1995:10 f.).

Due to its isolation from other land masses, there are no large land mammals and the native fauna of the Marianas is, like many remote Pacific islands, restricted. The first Europeans to reach Mariana Islands report that they encountered no mammals larger than a rat. Rats would probably have been introduced by humans, most likely in late prehistoric times (Steadman 1999). In contrast to other Pacific islands, there *were* other introduced animals such as pigs, dogs and chickens, prior to European contact (see Chapter 2). The primary edible terrestrial animal were species of land crabs, especially the Coconut crab (*Birgus latro*) and the mangrove or land crab (*Cardisom carnifex*), both of which are still so highly valued that the Coconut crab has almost been extirpated (Vogt and Williams 2004).

In comparison with land mammals, the avifauna on Saipan is more diverse, but is still not large. Several species of birds are seasonal residents and less than 20 species are permanent. Several species of doves, pigeons and seabirds were hunted in prehistory, and the archaeological record shows that birds that are now extinct in the Marianas were hunted by the first colonisers (Steadman 1999). Bats played an important role in the prehistoric economy, especially the fruit bat (*Pteropus marianus*). Fruit bats are highly prized and considered a delicacy by the Chamorro people (Vogt and Williams 2004).

4.4. Linguistic and genetic evidence of Chamorro origins

4.4.1. The Chamorro language origin

Several different hypotheses regarding the origin of the Chamorro language have been put forward since Chamisso, who visited Guam in 1817 during Kotzebue's voyage round the world, and Gaimard, who accompanied Freycinet on the *Uranie* in 1819, wrote the first short vocabularies of the Chamorro language in the 19^{th} century (Safford 1903). Almost 200 years later, the origins of Chamorro are not fully understood, but major advances in the field of historical linguistics in past few decades has allowed the geographic area of the Chamorro homeland to be better understood.

The Chamorro language spoken in the Mariana Islands belongs to the Austronesian language family. Of the more than 450 Austronesian (AN) languages spoken in the Pacific region, Chamorro and Palauan are the only two languages that do not belong to the Oceanic subgroup. Chamorro has often been classified as a Western Malayo-Polynesian (WMP) language, which places it in a different branch of the Austronesian language family from the more widespread Oceanic languages found on most Pacific islands (Blust 2000; Reid 2002). WMP languages are spoken over a broad area, in Palau and the Mariana Islands in western Micronesia, the Philippines, much of Indonesia, coastal southern Vietnam, Malaysia and as far west as Madagascar. While WMP is a controversial grouping, its languages can be sourced to 'Proto-Malayo-Polynesian', the proto-language that includes all the extra-Formosan Austronesian languages, including Oceanic (Hung *et al.* 2011:923).

The Chamorro language position within the Austronesian language family has long been a topic of discussion as its origin has been unclear. This is mainly because of language contact, after people first arrived in the Marianas, with a variety of other languages, both Oceanic and western Austronesian and in historic times, through colonial influence (Spanish, German, Japanese, American administration; Reid 2002; Blust 2000; Safford 1903).

Several different origins for Chamorro have been proposed. In 1984, Blust noted that the probable origin of Chamorro was in the southern Philippines or northern Sulawesi, noting also that the distinctive nature of Chamorro and Palauan (compared to other languages of the Philippines and Sulawesi) could be due to the high degree of isolation they experienced, in contrast to other WMP languages (Blust 1984-1985, 1988:56).

Sixteen years later, Blust (2000:103) stated that there are three main views regarding the linguistic position of Chamorro: (1) Chamorro is most closely related to the languages of the Philippines; (2) Chamorro is most closely related to one or more languages in Indonesia, and (3) Chamorro has no close relatives within the Malayo-Polynesian branch of the Austronesian language family.

The similarity between Chamorro verbal affixation to that of various Philippine languages has been recognised since Safford (1903), who noted that the language of the people of the Marianas is not a Micronesian dialect, but a distinct language with a vocabulary radically different from languages spoken in the Carolines, Marshall and the Gilbert Islands, sharing certain grammatical features with the Malayan languages as well as Tagalog and Visayan of the Philippines (Safford 1903:5). Topping and Dungca (1973:3) similarly suggests that the verbal system of the Chamorro language is closest to Tagalog and Ilokano of central and northern Philippines, but this could have been the result of language borrowing during trade between Filipinos and Chamorro. This was a possibility was also noted by Costenoble (1940) who claimed that the presence of various linguistic strata implied language contact. It should be noted that the number of paradigms found in Chamorro rules out simple borrowing as an explanation for their provenance. The fact that the Philippine and Chamorro paradigms that are similar are conservative retentions, rather than shared innovations, makes it harder to use this data convincingly to subgroup Chamorro with other languages.

In ‘Chamorro historical phonology’, Blust argues that innovation in the pronoun systems and various lexical innovations points to the fact that Chamorro is descended from a single language ancestral to all AN-languages outside Taiwan, that is, Proto-Malayo-Polynesian. The fact that Chamorro shows no close affinities with any other language within the Malayo-Polynesian group based on phonological lexical morphosyntactic evidence means it cannot be assigned to any sub-group lower than Malayo-Polynesian (Blust 2000:104). In the same paper, Blust claims that there are three major reasons for having the origins of the Chamorro language in the Philippines, and especially Luzon: (1) Geographical proximity, (2) Settlement time, population density, and migration potential and, (3) Linguistic evidence for migration in the 'Typhoon zone'.

Blust argues that neither archaeological nor linguistic evidence support the possibility that the Marianas were settled by way of Palau or Yap as a 'stepping stone'. Rather, all indications are that the Chamorros reached their historical location through a single movement from ISEA. Arguments based on geography, then, favour the Philippines over areas further to the south as a likely source region for the prehistoric peopling of the Marianas. Winter *et al.* (2012) and Fitzpatrick and Callaghan (2013) showed, however, that to drift or sail from northern Luzon to the Mariana Islands is improbable given prevailing currents and winds (Figure 8). Computer simulations demonstrated that there was 0% chance of either intentional (directed) or unintentional (drift) voyaging to the Marianas from Taiwan or from anywhere in the northern Philippines (Fitzpatrick and Callaghan 2013:851).

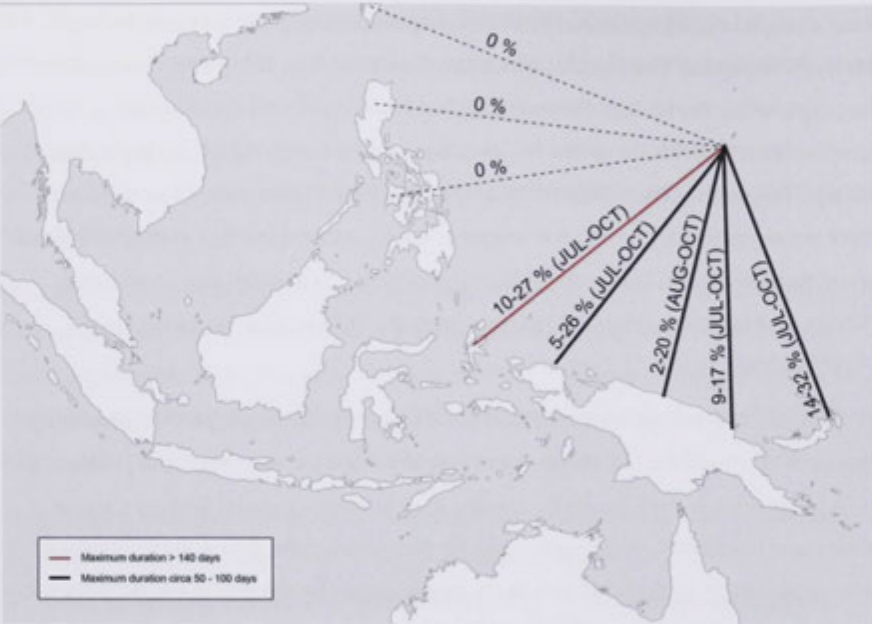


Figure 8. Success rate of drift and directed voyages (After Fitzpatrick and Callaghan 2013).

Blust also considers that since Austronesian speaking people first arrived in northern Luzon from Taiwan at ~5000 BP and later migrated south in ISEA, the population density in northern Luzon would have been higher. Since migrations were more likely to take place from areas of higher population density than from areas of lower population density, he thus favours the Philippines as the most likely region from which the Marianas were settled.

This assumption has not been tested archaeologically, and migrants who used boats to journey from Taiwan may not have not stayed in Luzon nor expanded north-to-south by a demographic wave of advance.

Blust's third argument is based on the Chamorro word *pakyo* meaning 'typhoon, storm, tropical cyclone' that reflects the Pan *baRiuS, PMP *baRiuh 'typhoon'. Blust argues that the Mariana Islands lie directly in the 'typhoon belt' that connects the Caroline Islands meteorologically to the central and southern Philippines, Taiwan, the Ryukus and southern Japan. Since typhoons are a frequently occurring weather phenomena in the Mariana Islands, Blust does not consider the word *pakyo* as being a loan word from

Tagalog, which has a very similar word for typhoon (*bagyó*). The 'Typhoon zone' lies approximately 10 degrees to 35 degrees north of the equator and typhoons rarely occur below latitudes of 10 degrees within the intertropical convergence zone, the so called 'doldrums'. Blust notes (2000:107): "In the western Pacific, the doldrums include the whole of Indonesia and New Guinea. Within the Philippines, typhoons are most frequent in Luzon and the northern Bisayas, and are extremely rare in Mindanao". Blust gives records of thirty typhoons that struck the Philippines in 1960-1970, and only one of these crossed Mindanao. Blust notes that if the weather system had been the same for four millennia the Chamorro word *pakyo* 'typhoon' is evidence that in migrating to the Mariana Islands, Chamorro speakers never left the typhoon zone, and since Chamorro is a MP-language, the Philippines and only the Philippines north of Mindanao, could be the point of departure for the colonisation of the Mariana islands (Blust 2000:106-107).

A typhoon is a storm where sustained winds reach wind speeds of 118 kilometres per hour and higher, which equates with a hurricane using the Beaufort wind speed scale (established in 1805). Blust argues that typhoons are very rare south of the northern Bisayas, which is true, compared to Luzon, but they do occur. From 1945 to 2011, the Joint Typhoon Warning Center has recorded 12 typhoons that hit Mindanao, which averages one typhoon every five years (http://weather.unisys.com/hurricane/w_pacific/). Another 15 tropical storms were recorded as affecting Mindanao during the same period. If the weather system has been the same for four millennia, as argued by Blust, this would mean that Mindanao could have experienced around 800 typhoons during the last 4000 years. Without being able to calculate wind speed and classify storms using the Beaufort scale or other modern systems, the people living in the Philippines 4000 years ago would probably not have distinguished between a strong tropical storm (63-117 kilometres per hour) and a typhoon (118-239 kilometres per hour), although they were undoubtedly knowledgeable about weather phenomena. The word *pakyo* could just as well refer to a strong tropical storm, which *do* impact Mindanao and other areas south of Luzon (Figure 9), so there is no compelling reason to assert a Chamorro origin in the northern Philippines from the word *pakyo*.

Figure 9. Chart of storms hitting Mindanao the last 50 years. Blue lines represent storms with winds speeds up to 117 kilometres per hour (http://coast.noaa.gov/hurricanes/).

The linguist Zobel assigned Chamorro to a putative "Nuclear Malayo-Polynesian" subgroup that contains Chamorro and Palauan together with Central-Eastern Malayo-Polynesian languages and most languages in western Indonesia, but not the languages of the Philippines, northern Sulawesi, Madagascar or Borneo. Zobel argues that based on verb morphology and morphosyntactical innovations, that Chamorro and Palauan are more closely related to the languages of eastern Indonesia than to languages of the northern Philippines, hypothesising that the centre of NMP was Sulawesi. He argued that NMP speakers migrated to the Mariana Islands from Sulawesi or possibly from the southern Philippines (Zobel 2002:430-432). Blust, however, claims that there is no phonological or lexical evidence for this view (Blust 2000:103), and the "Nuclear Malayo-Polynesian" hypothesis has not been widely accepted.

A third view was first articulated by Dyen (1965), based on lexicostatistical evidence. Dyen argued that Chamorro forms a primary branch of the Malayo-Polynesian linkage. Starosta and Pagotto (1985) considered grammatical evidence to link Chamorro with languages of the Philippines, but found that there is no corpus of shared innovations that could be used to justify a subgrouping connection between the languages (Starosta & Pagotto 1985; Blust 2000:104). The same point has been made by Reid (2002:92): "determining the actual subgrouping position of Chamorro is not possible from phonological evidence and even the morphosyntactic evidence [...] is not strong". Reid (2002:87) notes that Chamorro only reflects innovations that took place in Proto Malayo-Polynesian (before the dispersal of Philippine languages), reiterating Starosta's (1995) conclusions. Starosta claims that Chamorro shares a set of morphosyntactic innovations with some Formosan languages and are closely related to languages such as Kanakanavu, Paiwan, Amis, Atayalic and Saisiyat (Starosta 1995:694). Reid proposes that Chamorro is not closely related to Formosan languages, since there are archaic remnants in Chamorro of innovations that Starosta claimed were innovated at a later point - *after* its separation from Formosan languages (Reid 2002:92). Reid's arguments could suggest that, if there had been a southward colonisation through the Philippines, then Chamorro might have a northern Philippines origin (Winter el al 2012).

Recently Donohue and Denham (2010:226-227) note that with current linguistic data: "we cannot say that the northern Malayo-Polynesian groups represent higher branches on the tree and that the southern groups are farther (phylogenetically) from the source". The implication is that rather than a graduated dispersal of MP languages south of Taiwan, there was rapid dispersal and propagation of MP languages across most of ISEA. The dispersal centre of Malayo-Polynesian cannot be identified purely on linguistic grounds and potentially includes the southern Philippines/eastern Indonesia area in addition to the west Pacific (Donohue and Denham 2010:227).

The origin of the Chamorro language is clearly not fully understood, but it could be somewhere in the north or south of the Philippines, although it might also lie further south in areas such as Halmahera or Sulawesi.

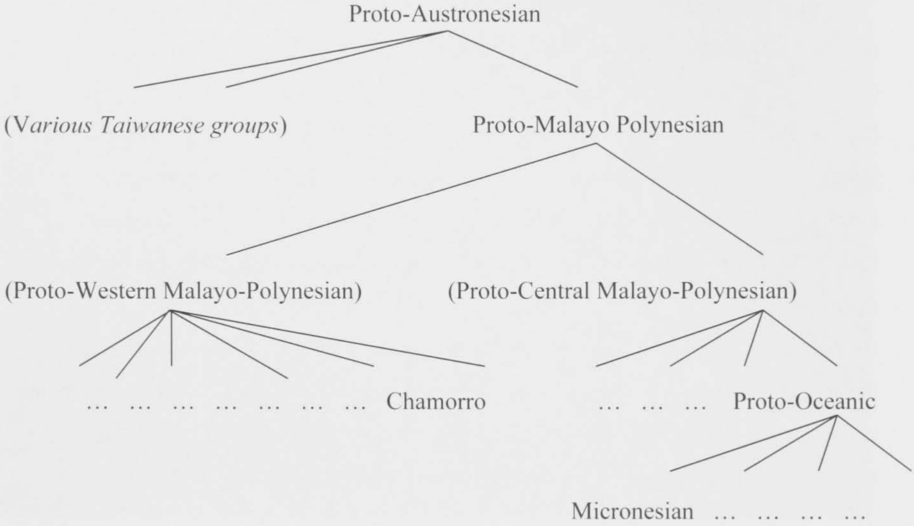


Figure 10. Simplified Austronesian family tree. Made and provided by Mark Donohue 2012.

4.4.2. Genetics

The analysis of genetic markers can offer a picture of inheritance and origin which ordinary archaeology cannot. Genetic studies (Plato and Cruz 1967) as well as more recent molecular studies of Micronesian microsatellites and mitochondrial DNA (mtDNA; Lum *et al.* 1998; Lum and Cann, 2000; Vilar *et al.* 2013), have shown that the indigenous people of the Marianas, the Chamorros, are quite distinct from other Pacific and ISEA people. According to studies made by Lynch *et al.* (2008) and Reiff *et al.* (2011), 85% of Chamorros belong to mtDNA haplogroups E1 and E2 which are relatively common (15-20%) in ISEA (Trejaut *et al.* 2005; Hill *et al.* 2007), but are otherwise rare (<5%) in other Pacific island groups (Lum and Cann 2000; Friedlaender *et al.* 2007; Vilar *et al.* 2008; Vilar *et al.* 2013). The remaining Chamorro lineages belong to a unique lineage of haplogroup B4 (Lynch *et al.* 2008; Reiff *et al.* 2011), which is a fairly common haplogroup in ISEA and Melanesia (10-20%) (Trejuaut *et al.* 2005; Hill *et al.* 2007; Vilar *et al.* 2008), but is the most common haplogroup (>85%) in Central and Eastern Micronesia (Lum and Cann, 2000) and in Polynesia (Sykes *et al.*

1995). The lineage B4a1a1a, also known as the *Polynesian Motif*, is the most common lineage of the B4 haplogroup in Oceania, and has previously been associated with the Lapita expansion (Lum et al. 1998; Merriwether *et al.* 1999; Lum and Cann, 2000; Vilar *et al.* 2008; Vilar *et al.* 2013:6).

In a recent study published by Vilar *et al.* (2013) mtDNA hypervariable segment 1 (hvs1) sequences were studied from 105 self-identified Chamorro volunteers (Guam n=85, Rota n=6, Saipan n=14) and 17 Saipan islanders of Carolinian maternal ancestry. These 122 sequences were compared to the 210 sequences from neighbouring archipelagos (Lum and Cann, 2000), as well as to other sequences previously published on GenBank (http://www.ncbi.nlm.nih.gov). In addition to these data, complete mitochondrial genomes were sequenced for thirty-two Chamorro individuals (Reiff *et al.* 2011; Vilar *et al.* 2012:8).

The results of the important Vilar *et al.* (2013:9-10) study are summarised:

- The 122 individuals studied yielded 19 unique hvs1 haplotypes.
- Of the 105 Chamorro lineages, 92% (n=97) shared mtDNA hvr1 transitions at base pairs (bp) 16223, 16362 and 16390 characteristics of haplogroup E1 and E2.
- 65% (n=68) of Chamorro lineages had an additional transition at bp 16051, a polymorphism that defines haplogroup E2.
- 28% (n=29) of Chamorro lineages belonged to E1, a haplogroup distinguished from E2 by the 16051 transition.
- The haplogroup B4 accounted for 8% (n=8) of Chamorro lineages, but 100% (n=17) of individuals of Carolinian ancestry from Saipan.
- Of the 25 haplogroup B4 lineages, lineage B4a1a1a made up 88% (n=22) of the haplogroup B lineages. All seven haplogroup B4a1a1a lineages from Guam and Rota had an additional transition at bp 16114 (C16114T) unique to those two islands. All B4a1a1a lineages from Saipan, the rest of Western Micronesia, ISEA, and throughout GenBank, lacked the 16114 transition.

The Vilar *et al.* (2013) DNA study of people from the Mariana Islands showed that three lineages accounted for more than 65% of the haplogroups; E1, E2 and the unique to Chamorro B4 lineage (the B4a1a1a lineage with the additional C16114T transition).

The haplogroups E1 and E2 clusters have been found in low frequencies in the Philippines, and the Sulawesi and Maluku islands of Indonesia (Hill *et al.* 2007; Vilar *et al.* 2012). None of the branch tips for either of the haplogroup E1 and E2 clusters were found outside of the Marianas. This factor is a probably indicative of a founder effect, where the two founding Haplogroup E lineages arrived in the Marianas with the first settlers perhaps 3500 years ago, and over a period of some 3000 years of isolation, the two ancestral lineages acquired a mutation that gave rise to the branch tips unique to the Marianas (Vilar *et al.* 2013:11)

The Vilar *et al.* study also revealed that the complete genome analysis showed a similar pattern to the hvs1 results. All complete genome haplotypes were unique to the Mariana Islands, but closely related (i.e. fewer than five mutations different) to haplotypes present in parts of ISEA, specifically Sulawesi, Sumba, the Moluccas, Borneo and the Philippines.

The complete genome E1a2 Chamorro lineages identified two individuals with an ancestral lineage. This lineage recently found among Chamorros has never been found among ISEA individuals previously. The ancestral form of E1a2 is similar to lineages (three or fewer mutations away) present on islands in eastern Indonesia and suggests there is a strong link between the two areas (Soares *et al.* 2008; Vilar *et al.* 2013).

The third high-frequency lineage found in the Vilar *et al.* 2013 study was the Chamorro unique B4 lineage (B4a1a1a lineage with the additional C16114T transition). On Guam and Rota this was the only B4a1a1a lineage found, while the C16114T was absent from 17 haplogroup B4a individuals of Carolinian ancestry from Saipan, as well as the 236 haplogroup B4a individuals from Palau, Yap, and the outer islands of Yap. The specific C16114T transition found at Guam and Rota is also absent from the B4a1a1a lineages from ISEA, Melanesia, Micronesia and Polynesia published in GenBank (Vilar *et al.* 2013).

The *Polynesian Motif* (the presumed hvs1 ancestral form with the B4a1a1a lineage) has been reported throughout Micronesia, Melanesia, and Polynesia (Sykes *et al.* 1995; Lum and Cann, 2000; Vilar *et al.* 2008), and is found in a low frequency in Sulawesi, the Moluccas (Hill *et al.* 2007; Soares *et al.* 2011) and the Bird's Head Peninsula of West New Guinea (Cascione *et al.* 2006 personal comment in Vilar *et al.* (2013). However, the B4a1a1a lineage with the C16114T mutation is unique to Chamorros, and is so far only present in individuals from Guam and Rota.

Vilar *et al.* suggest that the genetic homogeneity and uniqueness of this minority lineage to Guam and Rota may be due to a more recent migration from ISEA or a mutation of the B4 lineage common in the neighbouring Micronesian Islands Yap and the Carolines, where the frequency of the ancestral type (Polynesian motif) is high (Vilar *et al.* 2013:13).

The Vilar *et al.* (2013) study comes to the conclusion that the Marianas were probably settled between 5000 and 3500 years ago directly from ISEA, most probably from Wallacea (Sulawesi and the Moluccas) where E1a2 and E2a lineages have been previously identified and may have originated (Hill *et al.* 2007; Soares *et al.* 2008). Furthermore, based on the presence of the unique B4a1a1a lineage on Guam and Rota, Vilar *et al.* suggest a second, later migration to the Mariana Islands. The origin of this migration is unknown, but the specific lineage (C16114T) is so far not found in any other Micronesian archipelagos (Lum and Cann, 2000; Vilar *et al.* 2013), nor is it identified in the Tabbada *et al.* (2010) study of mtDNA diversity in the Philippines, or in selected islands of Indonesia (Soares *et al.* 2011). Vilar *et al.* suggest that the lineage might yet exist somewhere in the heavily-populated islands of eastern Indonesia: Sulawesi, Halmahera, the Moluccas, (Hill *et al.* 2007; Soares *et al.* 2011) or the Bird's Head Peninsula of West New Guinea (Cascione *et al.* 2006), where all three haplogroups are known, or are presumed, to exist (Vilar *et al.* 2013:15).

4.5. Palaeoenvironmental evidence for early colonisation of the Marianas

Several palaeoenvironmental projects have been conducted in the Mariana Islands and have mostly involved coring of lake and wetland sediments. The main focus of these investigations was to gather information about the prehuman environment and to use proxy indicators to examine the timing and magnitude of human impacts. Proxy indicators consist of changes to the microfossil record that indicate human colonisation, demographic growth, agriculture and landscape change.

Coring studies have been conducted at the Hagatna Marsh in Guam (Hunter-Anderson *et al.* 1989), Tipalao (Athens and Ward 1999), upland Pago River, (Ward 1994), Laguas (Athens and Ward 1999), at Hagoi in Tinian (Athens and Ward 1998), at a sinkhole in the Kagman area in Saipan (Dega, Gleghorn and Ward 2003) and in Lake Susupe in Saipan (Athens and Ward 2006).

From an archaeological point of view, the palaeoenvironmental data is problematic as it suggests a very much longer history of human occupation than is supported by the archaeological record. The reliability of estimates for the age of human arrival in the Marianas is a critical issue for this thesis and as well as Pacific archaeology, and therefore the palaeoenvironmental data requires a detailed and critical review.

The palaeoenvironmental stratigraphic records of the Mariana Islands indicate millennia (~8000 years) of stable forest growth on all the major islands, with some variation probably due to edaphic factors such as limestone versus volcanic soils. The limestone terraces of Saipan and Tinian probably had open forest conditions with scattered trees, bushes and grasses (Athens, *et al*. 2004:23).

The anthropogenic proxy indicators for human colonisation of the Mariana Islands include: charcoal particles, presumably from burning associated with land clearing; a declining frequency of native forest elements, such as: *Freycinetia* sp., *Randia* sp. *Ioxora* sp., *Guettardia* sp., *Piper* sp., *Pouteria* sp. and an increase in percentages of various grasses that reflects secondary growth associated with deforestation. An increasing prevalence of coconut (*Cocos nucifiera)*, and the appearance of betel nut (*Areca catechu*) and taro (*Colocasia esculenta*) are also used to indicate a human presence (Athens, *et al*. 2004).

The palaeoenvironmental records in the IARII Laguas core on the west coast of Guam indicate initial anthropogenic alteration of the Mariana Islands landscape by ~4300 cal BP when the first charcoal particles appear. By about 3900 cal BP, *Lycopodium* and *Gleichenia* ferns are noticeable in the record, and are associated with gardening and resource collecting activities by a small human population (Athens and Ward 2004 15; Athens *et al.* 2004). From a core in the Kagman sinkhole on the east coast of Saipan, Athens *et al.* note a shift in palynomorph frequencies at about 4520 cal BP which indicates a more open landscape (Athens *et al.* 2004:fig 6). A radiocarbon date (Beta-123091) (Layer V 190-200 cm) of 4160-3903 cal BP was reported as being associated with the proxies associated with first human impact, which include the presence of coconut and taro pollen in the record (Dega *et al.* 2003). Layer IV 146-154 cm) is much more recent and dated to 1610-1412 cal BP (Beta-123092).

In a core from Lake Susupe on the west coast of Saipan, the earliest potential indication of human activity occurs around 4860 cal BP is charcoal particles. By 4170 cal BP there is an abundance of charcoal particles and grass pollen (Athens and Ward 2006). These results predate the oldest archaeological sites by 1300-600 years, if the generally accepted date of 3500 BP for the colonisation of the Marianas is used. Furthermore, there are some inconsistencies in the dates from the Lake Susupe core 2. One dating sample (Wk-12846) that calibrates to 3720-3550 cal BP that could fit within the time frame of archaeological evidence of human presence in the Marianas, is stratigraphically out of place between two samples calibrated to 2710-2470 cal BP (Wk-13638) and 2751-2682 cal BP (Beta-186316) (Athens and Ward 2006:32). This suggests that the radiocarbon date that indicates earliest anthropogenic proxies comes from a mixed layer and should be treated with some caution (Carson and Kurashina 2012). Even if the dates of 4860 cal BP and 4170 cal BP are evidence of burning and a more open landscape, this does not necessary mean it was anthropogenic. Burning could be caused by natural fires, as a result of lightning strikes and volcanic activity (Anderson 2004; and see below). Considering that several of the islands in the archipelago are volcanic such an alternative does not seem too far-fetched, considering there is no archaeological evidence for human arrival this early.

The discrepancy between palaeoenvironmental indicators of human arrival in the Marianas at 4300 cal BP or earlier and the first archaeological evidence from sites dated to 3500 cal BP is too great to be easily accepted. The same ambiguous results are seen in other Micronesian islands such as Palau where archaeological dates from the Orrak site are around 2500-3000 cal BP (Fitzpatrick 2003) while the palaeoenvironmental dates are hundreds of years older at 3800-3300 cal BP (Athens and Ward 1999; Welch 2002 and 4500-4200 (Welch 2002; Athens and Stevenson 2012).

The use of palaeoenvironmental evidence as a proxy indicator of human activity is sometimes controversial in Pacific archaeology and critiques of it have been raised by several archaeologists, particularly in relation to island colonisation. The first appearance of charcoal, that can be caused by natural fires, as a result of lightning strikes and volcanic activity, is in many cases much earlier in the palaeoenvironmental record, but particles are often at too low a frequency to be indicative of human landscape manipulation (Anderson 2004). Although charcoal counts may increase, this doesn't necessarily mean there were more fires, as the quantities of charcoal preserved in the sediment are based on a number of factors such as size, type and proximity of fires, as well as the age and type of depositional environment and catchment (Wright 2005).

Anderson (1994) identifies the problem of distinguishing charcoal from natural fires on Mangaia Island in Polynesia, which might also be relevant to early charcoal in the Marianas: "While much is made of the initial appearance of charcoal at about 2500 cal BP in VT6 and TM7, it is not acknowledged by Kirch and Ellison (1994) that charcoal was also present by about 7000 cal BP in TIR-1" (Anderson 1994:846).

This problem is evident in the analysis of the core from the Kagman sinkhole in Saipan, where charcoal from the lower strata was not counted (Dega *et al.* 2003:33).

The archaeologist Hunter-Anderson (2009:131) notes:

"However, it is the case that charcoal particles were observed throughout the Kagman sinkhole soil exposure but were not quantified in samples from lower than 250 cm below the surface. […] According to the logic of Athens and colleagues, if the deeper (and presumably older) charcoal in samples from Trench 98-4 is as valid an indicator of fires as that seen in the samples from 250 cm and above, then people were present in Saipan as early as 7900 cal BP. If the deeper and presumably older charcoal is considered non-human in origin (no one so far has claimed people were present in Saipan by 7900 cal BP), then why not the younger charcoal, still a millennium older than archaeological evidence for human presence in Saipan, in this core?"

An alternative cause for deforestation and resulting tropical Pacific island savannahs could be a natural outcome of climatic conditions. Given prolonged periods of cooler and drier Pleistocene climate, savannah plant endemics likely evolved in the Marianas. Smaller forested areas, limited to moister and less exposed locales, with extensive open grasslands on ridges and hillsides, may have characterised Saipan, Tinian, Rota and Guam, during these times. During the early Holocene ~10 000 years ago, island savannah may have decreased, while conditions became wetter and more favourable for trees. Savannah plant endemism during this time is most probably a result of survival of Pleistocene endemics. Studies of climate during the mid-Holocene have shown that aridity and temperature were higher in the Pacific/Indonesia region (Hunter-Anderson 2009:132). McGregor and Gagan (2004) have recovered fossil coral evidence from the mid-Holocene that shows that there was a significant rise in Pacific sea-surface temperature around 7000 years ago peaking at approximately 6000 years ago. This might affirm that "increased long-term drought in the global palaeo-climatic record" occurred during the mid-Holocene in the western Pacific and that these drier conditions could have resulted in a higher frequency of natural fires (Hunter-Anderson 2009:133).

Climate variability is also pointed out by Haberle (2003:252), who notes that in cores from Papua New Guinea: "the interpretation of palaeoecological records from the Pacific Ocean region must clearly incorporate the influence of short-term climate variability on vegetation dynamics as a significant driving force of vegetation change during the mid to late Holocene".

A final concern noted by Anderson (2004), Wright (2005) and (Carson and Kurashina 2012) relates to the dating itself. Radiocarbon dates for cores frequently rely on peat, which can be contaminated by old carbon. It also appears that several dates come from mixed layers as in the Susupe core (Athens and Ward 2005). Finally, the fact that *Ipomoea batatas* (sweet potato) was found in the Kagman Sinkhole core and dated to at 1610-1410 cal BP (Dega *et al.* 2003:35) suggests that the integrity of the core or accuracy of the identifications are questionable. Sweet potato was introduced to the Pacific in prehistory by Polynesians and later distributed by Europeans, but has never been documented in the Pacific prior to 1000 BP.

5. Early sites in the Mariana Islands

The oldest prehistoric sites in the Mariana Islands share several characteristics. In a ICOMOS thematic study report, Clark (2010:107) lists the early site features seen in western Micronesia:

1. They are all coastal, often situated on beaches. Often in sheltered bays and coves, that protect sites from seasonal trade winds;
2. They are located close to marine and terrestrial resources such as mangrove patches, estuary/lagoon, fringing reef, barrier reef and beach flat/limestone forest;
3. Access to fresh water and stone resources was important. Early sites are most often located at points were the terrain gives easy access to the interior resources of an island, for example: plants and animals and lithic material and land for gardens;
4. Cultural remains from early sites consist mostly of discarded domestic items. While some sites have remains of dwellings such as post holes, hearths and fire places, these are insufficient to reconstruct the shape or size of the oldest dwellings, nor is the wider prehistoric settlement pattern (gardens, cemetery, resource extraction areas) well understood;
5. The oldest sites in the Mariana Islands are exposed to modern activity, to a greater or lesser degree, with several ancient cultural deposits and layers located at modern surface or shallow depth while others have been deeply buried by beach sands and alluvial/colluvial deposits;
6. None of the earliest sites in western Micronesia have returned evidence of any voyaging to other parts of Micronesia, but in the Mariana Islands, Saipan sherds have been found at Unai Chulu on Tinian Island, Mochong on Rota Island and from Laguas on Guam. No exotic materials to pinpoint the origin of the colonising populations of the Marianas have yet been found;
7. Only a few of the oldest prehistoric sites in Western Micronesia are adequately dated by radiocarbon, and ambiguity in the colonisation chronology has made it difficult to understand the process of Neolithic human migration in the Asia-Pacific region.

The colonisation of the Mariana Islands is usually accepted to be 3500 cal BP, however as mentioned above there are few sites that are reliably radiocarbon dated (Clark 2004; Clark *et al.* 2010). Many dates from early sites are on marine shell as little charcoal has been found, possibly because flotation has not been used in many excavations. The accuracy of shell dates is complicated by the absence of a firm ΔR value to apply to marine results, and few prehistoric sites have shell-charcoal radiocarbon pairs that can be used to estimate the reliability of marine ages (see Chapter 8.4). Nonetheless, some chronological sequences have been proposed for the Mariana Islands starting with Alexander Spoehr (1957:171-178) who proposed a simple chronology. Spoehr termed the distinct material expression of late prehistoric Chamorro culture as the Latte Phase/Period. The Latte phase is now dated to ~900-300 cal BP and sites are characterised by the presence of *latte* stones, a formal village layout, thick walled pottery, stone mortar-and-pestles, stone adzes, shell adzes, shell ornaments, simple fishhooks and gorges, implements of warfare such as spears and slingstones, and formalised burial practices (Carson 2014:325a).

Everything earlier than 900-300 cal BP, back to initial settlement at 3500 cal BP, is grouped to the Pre-Latte Phase. The Pre-Latte Phase is harder to define, as the material culture is more limited in comparison to the recent Latte Phase. The main cultural marker of the Pre-Latte Phase is a very thin and very well-made red-slipped and sometimes black-burnished pottery which is occasionally decorated with fine, lime-infilled, punctate-stamped, circle-stamped, and incised designs. This distinctive pottery is found in the deepest cultural layers and on archaeological grounds is the oldest pottery.

Spoehr's chronology grouped sites according to whether they contain one or other of the two pottery styles. The thicker and coarser 'Mariana Plainware' of large simple bowls belonged to the Latte phase. The thinner red-slipped 'Mariana Redware' ceramics found in the earliest deposits were from the Pre-Latte Phase. Spoehr's distinction between the two types of pottery was widely used by archaeologists and is still accurate today, although the lengthy Pre-Latte Phase has subsequently been now been divided into several components (Carson 2012b).

In 1983, Darlene Moore (Moore 1983, 2002) proposed a more refined version of Spoehr's chronology based on ceramic differences. Moore's chronology is divided into four major units:

1. The 'Early Pre-Latte Period' (~3500-2500 cal BP). The significant marker of this period is Red Ware, a lime-filled, impressed ceramic ware with thin, everted rims. The dominant vessel shapes are jars with sharply everted rims, and bowls with carinated shoulders.
2. The 'Intermediate Pre-Latte Period' (~2500-2000 cal BP). The characteristic pottery for this period is thicker than the earlier ceramic wares, however lime-filled impressed decoration is still present and shallow open bowls appear.
3. The 'Transitional Period' spans almost a millennium, from 2000 to 1100 cal BP. The pottery in this period has thicker rims and lacks the lime-filled impressed decorations.
4. The 'Main Latte Period' starts at 1100 cal BP and lasts until the Spanish arrival in the Marianas in the 16th Century. The characteristic pottery from this period has very thick rims and relatively thin walls and includes some very large sized vessels (Hunter-Anderson and Butler 1995).

John Craib (1990) proposed an alternative chronology in 1990 starting with the 'Tarague Phase' (3000-2500 cal BP), followed by the 'Ypao Phase' (2500-1200 cal BP), the 'Mochong Phase' (1200-400 cal BP) and leading into the 'Latte Phase' that, according to Craib, spans 800 to 300 BP (Craib 1990).

Moore and Hunter-Anderson (1999) renamed the intervals in Moore's 1983 chronology. In the revised chronology 'Pre-Latte' is replaced by the term 'Unai' which means beach in Chamorro and Hunter-Anderson and Moore renamed the intervals as 'Early Unai' (3500-3000 cal BP), 'Middle Unai' (3000-2500 cal BP), and 'Late Unai' (2500-1600 cal BP). The period formerly named 'Transitional Period' 1600-1000 cal BP was replaced by the term 'Hyong' (which means 'going out' in Chamorro). The only term that is still used is the 'Latte Period' (1000-400/300 cal BP) (Moore 2002). This thesis will use the refined Moore and Hunter-Anderson 1999 description of cultural phases.

Table 2. Spoehr's (1957) broad phases of Mariana Islands prehistory as subdivided following Moore and Hunter-Anderson (1999).

Phase	Subdivisions	Period	Approximate Calendar Dates
Pre-Latte Phase	Early Pre-Latte Period	3500-2500 BP	1500-500 BC
Pre-Latte Phase	Intermediate Pre-Latte Period	2500-1600 BP	500 BC-AD 400
Pre-Latte Phase	Transitional Period	1600-1000 BP	AD 400-1000
Latte Phase	Latte Period	1000 BP-AD 1521	AD 1000-1521

5.1. Early Pre-Latte Period 3500-2500 cal BP

Several sites belonging to the Early Pre-Latte period have been excavated in the Marianas and almost all contain characteristic ceramics often referred to as "Mariana Red Ware". Other artefacts from this period include shell rings and beads, stone adzes and flaked stone tools. A number of Early-Pre-Latte sites also contain ceramics decorated with lime-filling in finely-incised or dentate-stamped décor divided into two based on differences in pottery decoration. These are 'Achuago' and 'San Roque' named after two prehistoric sites on Saipan Island (Butler 1999). The decorated ware is comparatively rare and it is more common on Saipan Island and Tinian Island than on other islands. Guam has two early sites where 'Achuago' and 'San Roque' decorated ware has been found. They are Ypao in Tumon Bay on the west coast, and at the Mangilao Golf Course at Huchunao on the east coast. On Tinian Island, sherds with these décor elements have been found at the House of Taga site and at the Unai Chulu site at the north end of Tinian Island. On Saipan Island this type of pottery is found at Achuago and San Roque on the northwest coast and at Chalan Piao further to the south. Similar pottery has also been found in several excavations at Bapot in Laulau Bay on the east coast of Saipan (Butler 1995; Carson 2014).

5.2. The Intermediate Pre-Latte Period 2500-1600 cal BP

The Intermediate Pre-Latte Period follows the early Pre-Latte Period and this continuity led Hunter-Anderson and Moore (2001) to rename this period the 'Late Unai Period'. The ceramics from the Intermediate Pre-Latte Period are less complex with carinated vessels changing into robust, straight-sided pans, although the process of ceramic change took several centuries. The décor on the pots becomes less complex, comprised of bold impressed circles, bold lines and chevrons, some of which are lime-infilled. Through time this ceramic décor becomes less common (Rainbird 2004:107). According to Moore (1983), these new forms of vessels indicate a new form of food production and preparation, and suggest that cooking food on hearths changed to pit-roasting, since large flat-bottomed vessels are poorly suited for boiling or storage. Another theory is that salting food became important (Butler 1995; Moore and Hunter-Anderson 1999). These technological changes have also been related to population increase (Butler 1988, 1990: Moore 1983).

5.3. The Transitional Period 1600-1000 cal BP

During the end of the Transitional Period (1600-1000 cal BP), the ceramic once more changed from large open pans to thick globular bowls and large oval jars with a restricted orifice. The ware is made with a coarse volcanic sand instead of calcareous sand temper. Volcanic sand is a more suitable temper material for extended heat exposure, suggesting that these vessels were suited to both cooking and storage. The pottery changes indicate a shift in subsistence, which is likely to have followed a population increase and expansion of occupation into the interior. It also indicates an increased reliance on cooking plant food, especially starchy tubers and breadfruit. These vessels are also more suitable for storage, which might have been required with an increase in population (Moore 1983; Hunter-Anderson and Butler 1995:55).

5.4. The Latte Period 1000-500 cal BP

Around 1000 cal BP, the people of the Mariana Islands began to create raised groups of paired pillars made out of quarried limestone, sandstone or basalt. Pillars had on them a hemispherical capstone, and groups of pillars stand in double rows of three to seven, which are known as *latte* in the Chamorro language. *Latte* sets are found on all the main Mariana Islands and vary in size, but follow the same basic pattern of a parallel row of pillars in a rectangular plan. A study by Graves (1986) based on a sample of 234 *latte* sets on Guam, demonstrated that the number of columns ranged from six (three per row) to 14 (seven per row). *Latte* sets are most common in coastal sites, and typically occur in clusters that most likely represent villages or hamlets. The most impressive *latte* set is the House of Taga, on Tinian Island, with columns that are 5.3 m tall. *Latte* sets are associated with burials and midden debris, plain ware potsherds, and shell and bone refuse, which clearly indicate that Latte Period sites were habitation sites. Commonly associated with *latte* sets are large stone pestles and mortars of basalt named *lusong* in Chamorro. *Lusong* are commonly found placed between the end two pairs of *latte* set pillars and often had to be imported from a remote source. This might indicate that they were prestige items, or used to make or process an important food or drink. During the Latte Period, ceramics changed from thick globular bowls into taller pots with a restricted orifice, which is ascribed to a subsistence change that altered pot function (Butler 1990; Kirch 2000; Rainbird 2004).

During the Latte Period the first evidence of rice cultivation appears in the archaeological record. Domesticated rice (*Oryza sativa*) was first reported as a rice-impression in three pottery sherds from Mochong on Rotas Island by Takayama and Egami (1971). Since then rice remains have been found as spikelet impressions in two pot sherds from a cultural deposit at Tumon Bay (Hunter Anderson *et al.* 1995), and in four more instances from inland Guam (one sherd from a rock shelter and three sherds from three different open sites). Rice has been reported as a surface find at a coastal site on Rota Island and at the coastal site of Susupe on Saipan Island (Hunter Anderson *et al.* 1995). Other evidence for rice cultivation is a fragment of charred caryopsis of *O. sativa* found in soil flotation material from an undated cultural layer at Merizo in southern Guam, and a phytolith fragment from a sediment core in an inland freshwater marsh at Agat. No direct date is available for any rice remains found in the Marianas, but associated radiocarbon dates indicate that rice arrived in the Mariana Islands during the Latte Period, The Mariana Islands sites are the only sites in Remote Oceania where there is any evidence of rice cultivation.

What strengthens the possibility that rice was cultivated in late prehistoric times in the Mariana Islands are Spanish accounts from the 16th century. The Legazpi Expedition (1565) from Spain on their way to the Philippine Islands traded iron nails for bales of rice wrapped in mats. A Spanish Franciscan lay brother living in Rota Island in 1602 reported that rice was eaten at funerals, and on special occasions it was also used to pay compensation for social offenses (Hunter-Anderson *et al.* 1995).

It is also during the Latte Period that Pacific rats *(Rattus exulans)* first appears in the Mariana Islands, probably around 1000-900 BP, according to archaeological evidence (Pregill and Steadman 2009; Carson 2014). This is curious, since rats appeared with the first settlers in almost every other island in Oceania. When the Spanish arrived in the Marianas in 1521, there were no pigs, dogs or chickens, but there were plenty of rats that were a significant pest on the islands (Russell 1998).

The fact that the megalithic constructions (the *latte* sets), the mortars, the rice, and the rats seem to appear approximately at the same time, could indicate a new cultural influx entered the Mariana Islands. This influx could either have been brought by the Chamorro people if they travelled to ISEA where rice grows, or it could have been brought by a foreign cultural group arriving at the Mariana Islands with new ideas, plants and animals. It is hard to explain such a major cultural change as entirely caused by internal cultural development (Rainbird 2004).

6. Oldest material culture in the Mariana Islands

There are several early sites in the Mariana Islands and this chapter will describe the most significant sites and the material culture dating to the Early Pre-Latte Period. The purpose of the review of archaeological sites is to describe the oldest material culture sets and to examine the homogeneity of the earliest cultural assemblages. This is important for demonstrating that the first migrants shared a common material culture that was brought with them from their homeland and replicated in the Marianas. Unai Bapot has been regarded as being the best securely dated early site in the Marianas, dated to ~3500 cal BP or slightly earlier (Carson 2014). This work challenges this early chronology, both for Unai Bapot and for the Mariana Islands as whole, therefore, a comparison of early material culture from sites around the same age as Unai Bapot is important for the discussion of the Mariana Island chronology. The review starts with sites on Saipan in the north of the chain and proceeds to Guam in the south. Unai Bapot is not included here but will be discussed in Chapter 7 and 8.

6.1. Saipan sites

Figure 11. Saipan island, with marked Early Pre-Latte archaeological sites.

6.1.1. The Achuago site, Saipan Island

The Achuago site is located on the north leeward coast of Saipan Island with excavations carried out from 1988 to early 1990. The Achuago Archaeological Project involved examination of four parcels of land along the coast that were slated for beachfront hotel development. The project area is located in the northernmost segment of the western coastal plain midway between Tanapag and San Roque (Figure 11). The project area, with the exception of one portion of the Nansay tract, consists of geologically recent beach deposits. The archaeological work identified an area of early habitation deposits covering around 1500 m². In one area of the excavation (units 18, 23 and 24) a compacted floor-like surface, with associated large ceramic sherds, cultural debris, pit features and postholes, was encountered. The occupation at Achuago is dated by eleven radiocarbon samples. Nine samples are of wood charcoal, one sample is on marine shell and one is a peat sample. Two samples, from units 18 and 24, dated earlier than the others. The earliest (Beta 36190) is dated to 3470±120 BP (4010-3450 cal BP) (see Chapter 7) and was collected from the compact floor-like surface in the lower portion of the deposit in unit 24. The younger sample (Beta 36191) with an age of 3120±50 BP, (3280-2920 cal BP) comes from level eight in unit 18, also near the base of the deposit. These dates suggest that Achuago is one of the earliest sites with intact and well-preserved cultural material in the Marianas (Butler 1994:23).

6.1.1.1. Achuago ceramics

The Achuago excavation provided one of the largest and best-documented ceramic assemblages, consisting of some 100 000 sherds weighing 242 kg. A selected analytical sample of 3649 Early Pre-Latte sherds was chosen for detailed analysis. Results showed that the ceramics are of high technical quality, 90% of the sherds are slipped, or covered by a thin film, predominantly red, and the pastes are compact and well-prepared. The vessel walls are thin, measured sherds average around 5 mm thick, and the portion above the vessel shoulder is well polished. Butler comments that: "One of the most notable aspects of the early ceramic assemblages is the small number of vessel forms represented. There are only two major forms with some variants. The dominant form (~85% of all rims) is a small-to-medium-sized shouldered vessel (jar or bowl) with an inslanting neck, a constricted orifice, a sharply everted rim and a rounded base" (Butler 1994:23).

Only a few larger vessels were found, although they also had a small orifice size. Fragments of two 'bottle' forms were also identified, a short-necked carafe and the other having a small conical spout. The Achuago excavations also revealed a relatively large assemblage of 149decorated sherds. The pottery décor is found exclusively on the neck and shoulder areas of vessels. Two distinct styles of decoration were documented, and named the *Achuago* and *San Roque Incised* decorative styles. Both styles had been found previously in the Marianas, but the Achuago deposits yielded the first sizable collection. The sherds are very small, thus making it hard to reconstruct complete decorative panels. The dominant style, Achuago Incised (134 sherds, 88.7%) has a complex pattern of predominantly rectilinear incised patterns with the zones in between the major elements filled with very small punctations. The punctations are placed in diagonal, orthogonal or chevron patterns (see Appendix 1:63, 167:1) The other style, named San Roque, represented by only 15 sherds (9.9%) is decorated with bands of curvilinear garlands made by linking incised arches with small stamped circles or large punctations (see Appendix 1:63, 164:1; Butler 1995:356).

6.1.1.2. Stone artefacts

Among the artefacts recovered at the Achuago and Nansay excavations, 304 stone and coral artefacts were reported. They were categorised into two groups: *ground stone* and *chipped stone* items. The first group consists of 35 items: seven adzes, four hammerstones, ten slingstones, four abraders, nine abraded fragment and two pestles/pounders. The second group consists of 269 pieces categorised as flakes, broken flakes, fragments of flakes or cores. The small sample of ground stone tools was not associated with the earliest Pre-Latte component, except for abraders and hammerstones. None of the seven stone adzes found were in early layers, and probably belong to the Latte Period (Butler 1995:254-258).

The 269 chipped stone items found within the Achuago project is a rather small sample with a total weight of 1650 g. Seven different categories of raw material were designated. Three different cherts make up 69% of the total material. The other 31% of the stone material was categorised into limestone, volcanic rock, calcite and limonite. Approximately 63% of the chipped stone material was found in the Early Pre-Latte Period context, whereas 37% were from younger layers. Butler notes: "Given the scarcity of chipped stone material in the younger deposits, it is tempting to suggest that chipped stone technology may have been somewhat more important in early times, than later" (Butler 1995:263).

6.1.1.3. Shell Artefacts

The Achuago excavations produced a total shell artefact assemblage of 155 items. The largest artefact group was 'adzes and adze preforms'. Together with adze-related debris, this group comprises over 41% of the shell assemblage with 54 adze/adze preforms and ten fragments of *Tridacna* adze debris. Of these adzes and adze preforms 51 (78%) were from Late Transitional and *Latte* Period contexts. Only six shell adzes and two shell adze preforms were recovered from the Early Pre-Latte contexts. Three of these (one adze fragment, two preforms) were made of *Tridacna*, and the remainder were made of an unknown species of oyster and possibly a conch shell. It is possible these three items are intrusive, and derive from more recent deposits since *Tridacna* adzes are very rarely found in Early Pre-Latte Period contexts (Butler 1995: 244). Five shell fishhooks, one complete, and four fragments were recovered. The complete fishhook is possibly made of *Turbo* shell and is found in an Early Pre-Latte Period context, two others made from either *Turbo* or *Haliotis* are from the Transitional period and two are made from *Isognomon* (one is from a Latte Period deposit, and the other is without context).

Other shell artefacts found at Achuago are 16 pieces of worked shell, including fishhooks blanks and possible fragments of lures and eleven scrapers and scoops. All, except for one from the Early Pre-Latte Period, are associated with the Transitional Period or younger contexts. A total of 29 shell beads were recovered, with 28 from the Nansay excavation. Ten beads are from a single provenance (Burial 4) which is from the Spanish contact-period (Butler 1995:249). There are 14 beads from the Early Pre-Latte Period. Beads are made from three types of shell: *Spondylus* (n=13), *Conus* (n=11), and *Cyprea* (n=4). One bead is made from a small *Gafrarium* valve. Eighteen bracelets, rings and circlets made primarily of *Conus*, but also *Cellana* and *Trochus* were recovered, and of these, 14 items date to the Early Pre-Latte Period/ Early Transitional Period. Other worked shell found at the excavations include: one shell disc and an awl-like implement, both found in Early Pre-Latte Period layers, one unidentified artefact, and seven pieces of manufacturing debris (Butler 1995:252).

6.1.2. Chalan Piao site, Saipan Island

Chalan Piao is located on the southern part of the western coastal plain, between Chalan Kanoa to the north and San Antonio to the south (Figure 11). The Chalan Piao site was first excavated and described by Alexander Spoehr (1957). Spoehr estimated the site to be some 110 meters long and 45 meters wide, with the long axis oriented north-south. He excavated eight units (~23 cubic meters) in an area measuring 24 meters in an east-west direction and 18 meters in a north-south direction. Each unit was a five foot (1.5 m) square and at least 4 feet (1.2 m) deep with 6 inch (15 cm) levels. The excavation revealed a clear distinction between two layers, an upper layer (Layer 1) consisting of a dark grey sandy soil overlying a lower layer (Layer 2), a yellow-brown sand. Layer 1 was 20 cm to 30 cm deep and layer 2 over 120 cm deep. At 90 cm, Spoehr encountered concreted sand which required the excavators to excavate with crowbar and pickaxe. Pottery sherds were recovered from the concreted sand at a depth of 170 cm. The water table was found at 180 cm below the surface. Pottery and artefacts of stone along with worked marine shell were recovered including a basalt pestle, a *Conus* shell bracelet and a stone net sinker on the surface. Two shell adzes were found in layer 1, one at the bottom of the layer or possibly from the top of layer 2, and a cylindrical stone adze excavated from the lower part of layer 2. A collection of 1136 ceramic sherds were analysed and grouped into four different categories: Marianas Red (397 sherds), Marianas Plain (586 sherds), Marianas Grey (buff to dark grey 152 sherds), and one lime-filled Trade Ware sherd. The Marianas Plain ware was the dominant ceramic type in layer 1, and Marianas Red was the main ceramics in layer 2.

An unworked pearl oyster shell recovered at a depth of 45 cm from the upper part of layer 2 was submitted for radiocarbon dating. The shell has an uncalibrated age of 1527 BC±200 (Spoehr 1957:66). This was later corrected to AD 220±450 (Cloud *et al.* 1956:87). The first, older date, made a greater impact than the younger age amongst archaeologists and historians, and Chalan Piao was for a long time considered to be the oldest archaeological site in the Mariana Islands. Now, most archaeologists working in the region recognise problems with the determination as no reservoir or fractionation correction was applied (Moore *et al.* 1992).

In June 1989, the Chalan Piao site was again excavated by Micronesian Archaeological Research Services (MARS). Five one-meter squares were hand excavated and five trenches were excavated by backhoe. The hand excavations were taken to a depth of 90 cm until the sand was too cemented to excavate. Two stratigraphic layers were exposed: The upper layer, layer 1 varies from 10 to 30 cm and consists of dark brown sandy soil. Layer 2 is a yellowish-brown sand layer extended down to 90 cm, where it was indurated and too difficult to excavate.

The surface finds were a mixture of material from different cultural periods: items from the Japanese period, Latte Period pottery and Pre-Latte Period material such as Marianas Red Ware and *Conus* shell beads. Even in layer 1, objects from a range of different time periods were encountered: WWII cartridges, broken glass, a pig tusk and a mixture of Latte Period and Pre-Latte Period pottery. Layer 1 was obviously disturbed.

In layer 2, no intact cultural features were encountered. The cultural remains primarily belong to the Pre-Latte Period. Excavated items were *Conus* shell beads and rings, *Cypraea* shell beads, and Marianas Red and Marianas Plain ware. A few decorated pot sherds with lime-filled designs were also found. The 1989 excavation resulted in radiocarbon dates derived from two composite charcoal samples, since insufficient amount of charcoal was collected to date a single sample. Sample 1, from the top of layer 2, came from arbitrary levels 41-71 cm below datum, and Sample 2 was from the bottom of layer 2, 71-110 cm below datum.

Sample 1 gave a radiocarbon date of 2930±90 BP (Beta 33390), which when calibrated gives a date of 3270-2860 cal BP. Sample 2 yielded a radiocarbon date of 3210±100 BP (Beta 33391) which calibrates to 3640-3210 cal BP.

A total of 2213 sherds were analysed from the Chalan Piao excavation. Most (1977) were undecorated vessel body sherds, 142 were undecorated rim sherds, 52 were undecorated shoulder point sherds, 1 undecorated sherd had both a rim and corner point, and there were 59 decorated sherds (2.7%) of which 10 were rim sherds. Sherds with both Achuago Incised and San Roque Incised décor were found. The Early Pre-Latte pottery from Chalan Piao consists of three well made, thin-walled vessel forms, including jars, bowls, and vessels with elaborate carinated contours. The temper is primarily calcareous sand mixed with quartz, and some sherds have volcanic inclusions. Less than one percent of the Early Pre-Latte sherds are decorated and the trend is a simplification in design over time.

The lithic material from Chalan Piao consists of a few worked artefacts: a net sinker, a polished adze, an adze blade fragment, six basalt tool fragments, two spherical balls of coral and some chert debitage. Six different stone materials were recorded: basalt, calcite, chert, coral, limestone and limonite. All of these materials are common on Saipan, but only coral and possibly limonite are local to Chalan Piao. Most worked stone was found on the surface, and only debitage from basalt and chert, and abraders made of coral were found in the excavation.

A total of 456 shell beads were found, making this one of the largest bead assemblages in the Marianas. Furthermore, 18 fragments of *Conus* rings, shell discs of *Conus* shell, cowrie shell beads, Tridacna adzes, and modified sea urchin spines were recovered. Incomplete shell artefacts were found, indicating that the shell tools and ornaments was manufactured and used at the site (Moore *et al.* 1992).

6.2. Tinian Island sites

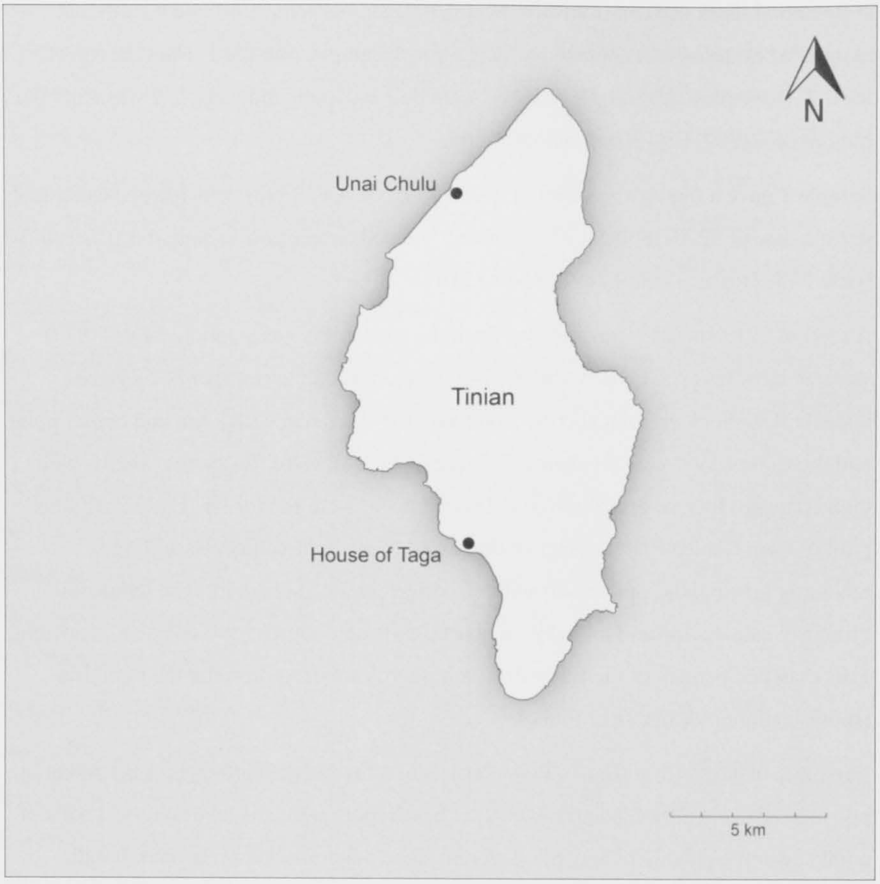


Figure 12. Tinian island, with marked Early Pre-Latte archaeological sites.

6.2.1. The Unai Chulu site, Tinian Island

The Unai Chulu site is located on the northwest coast of Tinian Island, the third largest island in the Marianas group. Tinian covers an area of 59.2 square kilometres and lies 4.5 kilometres south of Saipan Island. The site includes the area of Unai Chulu (known as the White Beach 2 by the WWII US Armed Forces Landing Operation) and its immediate vicinity. The Unai Chulu site has been heavily disturbed by mechanical and manual excavations made by Japanese groups searching for the remains of casualties from WWII battles. Construction of an access road in 1994 further disturbed the site.

In 1993, subsurface testing of Unai Chulu was conducted by Craib (1993). The test-excavation indicated cultural deposits covering an area of 7000 m^2 down to a depth of at least 1.5 meters. In July-November 1994, systematic subsurface testing commenced, informed by Craib's excavation the year before. 239 shovel test pits 0.5 x 0.5 m and 23 test units 1.0 x 1.0 m were excavated. A 12 x 12 m block of contiguous 2 x 2 m units and a deeper excavation of a 4 x 4 m block within the larger block was excavated. Based on the shovel test pits, the area of the whole site of Unai Chulu is estimated to be at least 9.6 ha. The occupation sequence at Unai Chulu spans approximately 3500 years to the present (the dating will be discussed in Chapter 10) and is subdivided into seven components based on 31 radiocarbon determinations. Thirteen charcoal dates derived from the 4 x 4 m block excavation show that Unai Chulu was initially occupied from the Early Pre-Latte 3500-3300 cal BP, to 1000 cal BP. Other dates from the test excavation samples prove likely that the site was occupied continuously from the Early Pre-Latte Period up to the 19th century (Haun *et al.* 1999).

6.2.1.1. Ceramics

The excavations at Unai Chulu yielded large amounts of pottery from the earliest period of occupation (Early Pre-Latte Period) on Tinian Island, in addition to large quantities of ceramics from the Early Transitional Pre-Latte period. Ceramics from the Latte Period were scarce and were only found in the uppermost stratum (Haun *et al.*1999:58). A total of 198 700 ceramic sherds were found at the Unai Chulu excavation; 56 551 from test units and 142 149 from the block excavation. A total of 3835 rim and decorated sherds were studied to provide ceramic attribute data such as vessel size, vessel shape, surface finish, temper and décor. Of these, 148 sherds (3.9%) were decorated. Approximately 68% of the decorated sherds derive from the earliest contexts in Stratum VI and Stratum VII. Several sherds are decorated in the two styles referred to by Butler (1995) as San Roque Incised (sherds decorated with bands of curvilinear garlands made by linking incised arches with small stamped circles or large punctations), and the Achuago complex pattern (predominantly rectilinear incised patterns with the zones in between the major elements filled with very small punctations placed in diagonal, orthogonal or chevron patterns).

6.2.1.2. Non-ceramic artefacts

A total of 4981 non-ceramic artefacts were found at the Unai Chulu excavations, but only diagnostic artefacts from the 4 x 4 m block-excavation were analysed. The sample includes 197 artefacts identified as fishing gear, manufactured from shell, bone and stone that would have been used for both inshore and pelagic fishing. There were 28 one-piece fishhooks and gorges, primarily manufactured from *Isognomon* shell, two composite fishhook pieces, 140 blanks/preforms and one sinker (Haun *et al.* 1999:84-90).

Approximately 2094 flaked lithic artefacts were recovered from the Unai Chulu excavations. Of these, 340 lithics were found in the 4 x 4 m block excavation. The number includes nine cores and 331 flakes manufactured from basalt, chert, limestone, chalcedony, siltstone, coral and unidentified rock. Out of a total of 337 artefacts classified as tools, 212 were from the block excavation.

The Unai Chulu category 'Tools' include: stone and shell adzes, choppers, hammerstones, chisels, abraders, bone points, scrapers, awls, picks, and slingstones. The raw material included: basalt, coral, limestone, echinoderm pieces, scoria, bone, shell, chalcedony, siltstone, pumice and quartzite. All of the seven stone adzes from the 4 x 4 m block excavation were found in the early strata V-VII. Five basalt adze fragments came from Stratum VII, while a limestone adze, and one adze of unidentified stone came from Stratum V. All of the fifteen shell adzes (all made from *Tridacna*) encountered in the 4 x 4 m excavation (except for two, from Stratum I), come from Stratum I/II and IIIb.

The stratigraphic data for flaked lithics is approximately the same as for the stone adzes where the majority are found in early layers. Of 316 recorded flakes, 246 or approximately 78% were recovered from the earliest layer, Stratum VII, 28 (9%) from Stratum VI, and one from each of Stratum V and IV. Twenty-six (8%) flakes were found in Stratum III, dated to approximately 2200-2000 BP, and 14 flakes (4%) were found in Stratum I, dated from 2000 BP to modern times (Haun *et al.*1999).

Data for the distribution of non-human bones in the 4 x 4 m block excavation shows that the majority of faunal remain came from the earliest layers. A total of 8702 bones were counted from all strata with a total weight of 1377 g. Of these, 5253 (60%, 1048 g) derived from Stratum VI and VII, and were mostly fish and birds, but also included turtle and bat bones.

6.2.2. The House of Taga site, Tinian Island

The House of Taga is the most famous archaeological site in the Mariana Islands. It is the largest *latte* structure in the island group and is revered as a symbol of Chamorro culture. The structure was introduced to Europe by Lord Anson after his visit to Tinian Island in 1742 (Anson 1748). Hans Hornbostel carried out an archaeological survey on the site in 1924 and found a cultural layer associated with the megalithic structures which dated it to the Latte Period. Alexander Spoehr (Spoehr 1957) excavated four test trenches with depths of ~120 cm to 180 cm. Spoehr did not find much evidence of early occupation at the House of Taga, although he notes: "With sherds found at a depth of over five feet below the surface, the site must have been occupied for a good many years" (Spoehr 1957:98). In 1958, Marcian Pellet, a former field companion to Spoehr, excavated 30 meters inland from House of Taga and discovered more than two meters of deep cultural deposits. The lowest and oldest layers contained red-slipped pottery, some of which was finely decorated (Cordy 1980; Carson 2014).

The House of Taga was again excavated in 2011 with a second season in 2013 by Hsiao-Chun Hung and Mike Carson. Although no full report of the excavation has been made there is some published information (e.g. Carson 2014). Hung and Carson excavated a 2 x 2 m trench north (landward) of House of Taga and a seaward (south) area of 2.5 x 7 m that was later expanded to more than 90 square metres. The oldest cultural deposits were found in the southern trench in layer VI, a sandy silt layer at 2 m where evidence of cultural activity such as artefacts, midden material, cobble-boulder paving stones, stone alignment, rubbish-pits, postholes, and hearths were identified. Layer VI was dated with seven radiocarbon dates. The earliest was on an *Anadara* sp. shell which was calibrated to 3600-3140 cal BP, and the most recent came from charcoal with a calibrated age of 3370-3210 cal BP.

6.2.2.1. Ceramics

Thousands of pieces of pottery were found at the excavations of the House of Taga with more than 350 decorated pieces, making it the largest collection of early-period decorated sherds in the Marianas. At least four different decorative systems were used: paddle impressed rows of circles, lines of chevrons or garlands, and detailed point-impression. The two different décor systems, most often reported from early sites in the Marianas, San Roque Incised and Achugao incised (Butler 1994) were also identified. The vessel forms reported from the excavation consist of a small number of bowls with orifice diameter in the range of 8-28 cm (Carson 2014:125-128).

6.2.2.2. Lithics

Carson (2014:128) reports flaked chert and volcanic stone, almost all showing edge use-wear. Chert was more commonly found in the earliest layer and volcanic stone was most abundant in layer III.

6.2.2.3. Shell

Shell artefacts include *Tridacna* adzes (one produced from a hinge in layer VI), one adze manufactured from *Cassis cornuta,* deriving from the bottom layer (Carson, personal communication, Jan 2014), beads, bracelets, and pendants most commonly made out of *Conus* sp. Carson also reports rare beads made out of *Cypraea* sp. A few rotating fishing hooks made of *Isognomon* sp. were also present (Carson 2014:128).

6.3. Guam Island sites

Figure 13. Guam Island with marked Early Pre-Latte archaeological sites.

6.3.1. Ritidian

The Ritidian archaeological site at the northern point of Guam is today a broad sandy beach of calcareous sand deposits more than 2 m thick. Sand deposits have built up along the seaward edge of the raised limestone karst plateaus of Pliocene or Pleistocene age from gradual events and episodic storm surges, and form a substantial sand plain on the northwest side of the point.

Archaeological remains described in the general area include several small and damaged late prehistoric *latte* sets, surface artefacts, and the site of a Spanish church dating to the late 17th century. Recent archaeological excavations at the Ritidian site have revealed two limited-use cultural deposits resembling short-term campsites, approximately 150 m landward of the beach berm, separated by more than 1 m of storm surge deposits and other non-cultural sandy accumulations (Carson 2010:18). The upper layer was dated to 3010-2790 cal BP on charcoal, while the deeper cultural layer (emplaced directly over a coral reef) was dated 3550-3060 cal BP on *Anadara* sp. shell and 3620-3140 cal BP for *Halimeda* sp. algal bioclasts. Both layers yielded early-type, plain, very thin, red ware pottery.

The fact that seasonal rainfall variability results in periodic water shortages, especially in the limestone formations of northern Guam, makes Ritidian a likely short-term campsite. Caves at the base of the limestone cliff were likely to have been used for water collection, but the amount of freshwater was not sufficient to support a large population. This is also suggested by the low frequency of pottery fragments, occasional shellfish remains, and the small amount of other cultural material (Carson 2010:8). So called 'short-term camps' might have been a major site type in western Micronesia during the colonisation phase (Clark 2010).

At 2700 cal BP, patches of stable backbeach were available near the base of the limestone cliff, and a more intensive residential activity took place. This is supported by archaeological finds of pottery fragments, stone tools and shell beads. Residential use appears to have continued uninterrupted over several centuries as the beach prograded and offered increasingly larger habitable space. By 800- 700 BP the sand plain had expanded and could support a wide-spread habitation. Archaeological evidence for this is remains of megalithic stone *latte* pillars and capstones, along with stone food pounders and mortars that could reflect more intensive food production by a larger population (Carson 2010:9).

6.3.2. Tarague

The Tarague embayment is located on the northeastern coast of Guam and stretches from Mergagan Point on the west to Pati Point on the east (Figure 13). The area is used by the United States Air Force personnel for recreation, weapons testing, explosive ordnance disposal and water supply. Guam's Northern Province is a generally flat karst plateau bordered by steep cliffs of coralline limestone. The karst plateau is tilted towards the southeast with a height of 183 m above the present sea-level. The outer limit of the plateau is characterised by steep cliffs that fall directly into the sea, or drop onto a narrow shelf of land that comprises the coastal plain. Rainwater drains through the porous limestone and creates a fresh water lens floating on the underlying, heavier salt water. Prehistorically, water would have been available through springs, seeps and limestone sinkholes that are 60 to 235 m from the shoreline. A fringing reef of 80 to 200 m protects the beach from open ocean waves, and a narrow channel through the reef is located at the midpoint of the embayment, allowing small sized vessels access to the open ocean.

Tarague was identified as an area of archaeological interest by Hornbostel in the 1920s, because of the presence of numerous *latte* structures. Hornbostel may have been referring to the distribution of late prehistoric villages rather than limestone capstone and pillars (Clark 2010). Shortly after World War II, D. Osborne (Liston 1996) conducted surveys and carried out limited excavations at 26 archaeological sites in the Mariana Islands. The main focus of his work was the megalithic *latte* structures. In 1952, E. Reed (Liston 1996) surveyed areas of Guam for the U.S. National Park Service with an aim to protect, preserve, and possibly to develop prehistoric and historic sites. Reed notes finds of pot-sherds that indicate a continuous occupation area from Uruno to Ritidian Point, both on the north coast of Guam. The sites that he visited on the northern coast include Hilaan Point, Haputo Point, Uruno Point, Ritidian Point, Tarague beach, Janum, Pagat Point, and Pago Bay.

From 1967 to 1969, E. Ray conducted archaeological investigations in the Tarague embayment for his graduate thesis. Ray carried out a small number of surveys, and excavated 12 test pits (Ray 1981). Ray's survey was limited to the central area of Tarague near the channel, and included the beach and the strand area. Nine of Ray's test pits showed evidence of *Latte* Period occupation of the embayment stretching from just to the west of Tarague Channel to midway between the channel and Tagua Point. Pre-Latte Period deposits were encountered in the central portion of the site. Two radiocarbon dates were obtained from Ray's test pit Nr. VII. Charcoal from a small fire pit in Stratum 3 (150 cm-160 cm depth) gave a date of 2400-2000 cal BP, while charcoal from a hearth feature in the lower layer, Stratum 5 (260 cm depth), had an age of 2300 -1800 cal BP. Ray concluded that there was at least one break in the archaeological record, rather than a continuity, based on the presence of two different types of pottery.

In 1977, F.R. Reinman conducted a comprehensive archaeological survey of large portions of the island followed by test excavations at five sites. The survey included almost the entire coastal margin of the island. Of the 138 sites located, only 37 were in the north. At the northeast coast, an area defined by the raised limestone terraces that extend from Pati Point to Pago Bay (Reinman 1977:8-11), Reinman recorded twenty archaeological sites. Six of them contained a total of 28 *latte* structures, with 20 of these located at one site, Mocham (MaGma-2).

In 1980, H. Kurashina and others from the University of Guam conducted archaeological investigations near a poorly-preserved *latte* set in the general vicinity of Ray's test pits southwest of the Tarague Channel (Kurashina *et al.* 1981; Kurashina and Clayshulte 1983a, 1983b; Moore 1983). The aims of the project were: to learn the origins of human habitation on Guam from a cultural history perspective; to try to determine cultural and natural processes which could influence culture change as seen from archaeological data; and to try to understand the use of space within the context of island ecology. A full report on this site (7-0015) has not yet been published.

The fieldwork consisted of a survey of the coastal littoral zone between Mergagan Point and Tagua Point and an excavation of a total of 12 square metres. A portion of the excavation was a 1 x 3 m investigation known as the South Profile, which disclosed a stratigraphy extending to 6.2 m depth before limestone bedrock was encountered. This bedrock was tentatively identified as Merizo limestone, which has been dated to about 1500 B.C. (Liston 1996; Moore 1983:61, citing Easton *et al.* 1978). The 'South Profile' consisted of ten layers with the basal layers 9 and 10 having no cultural material. The top eight layers, which extended to a depth of 3.3 m below surface, contained cultural material from both the Pre-Latte and Latte Periods interspersed with stratigraphic disconformities (Liston 1996). Kurashina *et al.* (1981:61) also identified an area that they interpreted as a *latte* stone quarry.

Moore's (1983) study was designed to measure cultural change from an attribute analysis of pottery sherds in correlation with radiocarbon dates from Tarague, and it resulted in a pottery seriation. The study of the variation in four attributes (temper content, wall thickness, surface treatment, and rim form), showed temporal variation (Liston 1996:84-87). In contrast to Ray, Moore did not find a stratigraphic gap marking the end of the Pre-Latte Period from the Latte Period. Moore (1983:216) suggested that technological changes occurred gradually over time, rather than abruptly as Ray (1981) had concluded.

In 1986, Moore and Amesbury conducted archaeological investigations on the west end of the Tarague embayment. They excavated five 1.0 x 0.5 m and one 1 x 1 m test units at the eastern end of the recreation area. Two radiocarbon samples on charcoal from Test unit 6, the unit farthest inland, indicated occupation during the Transitional Period and Latte Period. The date from a sample collected in dark brown sand at 70 cm to 80 cm below surface in layer III, was calibrated to AD 1220-1396. The upper portion of the underlying layer, a loose, tan, culture-bearing sand, rendered a calibrated radiocarbon date of AD 890-1130 (Liston 1996: Moore 1983).

In 1995-1996, large archaeological surveys and excavations were carried out at the Tarague embayment within the Tarague Legacy Project. The project area covered the coastal embayment of Tarague from Mergagan Point in the west, to Pati Point in the east. The survey and archaeological testing resulted in the recording of 138 historic and prehistoric sites. The large number of archaeological sites represents a wide array of activities extending from Pre-Latte Period to the recent period of World War II and the post-war development of Andersen Air Force Base (AFB).

The prehistoric sites at Tarague represent different activities of human use such as habitation, agriculture, resource collection etc. Sites with mixed midden debris, artefact scatters, and *latte* stones, have been recorded as habitation sites, either permanent or temporary, based on the size of the site. Other suggested uses for the sites are water catchments, fishing camps, and burial areas (Liston 1996).

6.3.2.1. Ceramics

A total of 714 excavated pottery sherds from seven sites were subjected to an attribute analysis. The sherds from these sites represent nearly the entire occupational sequence of Guam, beginning with the mid-to-late Pre-Latte Period and continuing into the early historic period. The early pottery from Tarague suggests the sites were used from approximately 2500 cal BP (Liston 1996). Added temper sand in the pottery varies across the sites. The volcanic sand temper (VST) inclusion varies from 4% to 100%, but is clearly the dominant temper type. The calcareous sand temper (CST) inclusions vary from less than 3% to 44% and the mixed sand temper (MST) inclusions vary from less than 1% to 53%. In general, the sites with lower percentages of VST seem to be earlier than the ones with higher percentages of VST (Liston 1996:183).

The pottery was also categorised by different rim types. Rim sherds were sorted into the two major types originally described by Spoehr (1957), Type A and Type B. The lip of Type A rims has the same thickness, or is thinner than the vessel wall. The lip of Type B rims is wider than the vessel wall. Rim types can serve as temporal markers. Over time in the Mariana prehistory, the percentage of Type B rims gradually increases, while the percentage of Type A rims gradually decreases. Type B is the most common rim type from the Latte Period pottery collection, but Type A rims occur throughout the sequence (Liston 1996:162). The rim types at Tarague correlate very well with the temper distribution in the pottery examined. Where the majority of the rim sherds are Type B, volcanic sand is the most abundant temper, and there is a higher percentage of calcareous sand where Type A rims are more frequent shape. Ceramics from the seven Tarague sites indicate that at least three of them (Sites 8-1588, 7-1605 and 7-1614) contain components that represent more than a single temporal occupation. Moore (1983) suggests that radiocarbon dates and the pottery from Sites 8-1588 show that by at least 2500 BP, people were living intermittently, if not permanently, in localities quite far from the beach. She speculates that population pressure, or something else, made people move inland. The inland area was being used early in Tarague's occupation sequence, but pottery distribution indicates that the inland and upland areas became more utilised during the Latte Period (Liston 1996).

6.3.2.2. Non-ceramic artefacts

The non-ceramic artefact assemblage from Tarague was collected from surface and excavation contexts from 18 sites. This assemblage of 104 artefacts includes sea urchin spine tools, shell and stone adzes, slingstones, abraders, beads, fishhooks, pestles, choppers, blades and lithic manufacturing materials (including hammerstones, cores, flaked stone, and debitage).

6.3.2.3. Lithics

Eight stone adze fragments manufactured in three different materials (andesite, andesite porphyry, and basalt) were collected during the Tarague survey. No adzes or adze fragments are reported from the site excavations. The stone adze assemblage includes one almost complete adze minus the bit, five butt ends, and two distal ends with broken bevels (Liston 1996). The andesite, andesite porphyry, and basalt are all local material to Guam, however are not found within the Tarague embayment, only at southern Guam.

6.3.2.4. Slingstones

Three intact slingstones and one fragment were collected during the project. They were all made of recrystallised limestone.

6.3.2.5. Flaked stone assemblage

Only a small assemblage of flaked stone artefacts was recovered from the Tarague project, and this was divided into four categories: choppers, blades, cores and flakes. Five basalt choppers and two basalt blades were collected from the surface of the sites. Four cores of andesite and basalt were recovered, one at the surface and the others from excavations. Twenty-six artefacts were classified as flakes or debitage and were manufactured from four different materials: basalt, pyroclastic rock, chert, andesite porphyry and limestone. Of these, twenty were found in an excavated context, and six at the surface.

6.3.2.6. Shell artefacts

Twenty-five shell adzes and adze fragments were found in the Legacy project. This is the largest artefact group, except ceramics. All adzes/fragments are manufactured from *Tridacna* sp., except for one manufactured from *Conus* sp.

6.3.2.7. Beads

A total of nine bead-like objects made from shell or limestone were recovered from Tarague. Of these, seven were found at one single excavation unit, and five of these in the same layer close to the surface. Six of the beads were circular, one is semi-rectangular, and two are sub-rectangular.

Based on the artefacts found at Tarague, the sites seemed to have been used for several different purposes: ocean exploitation (fishhooks, fishing weight), food processing (pestles, choppers), woodworking (adzes), lithic manufacturing (hammerstones, flakes, cores, and debitage), and adornment (beads) (Liston 1996:211).

6.3.2.8. Radiocarbon Dating

Nine radiocarbon dates from charcoal were obtained from the Legacy project. The dates show that the Tarague embayment has been used by people from the 3th millennium to modern times. The oldest sample, a date from palm wood of 2680±110 BP (Calibrated 3070-2450 cal BP) from layer III at site 7-1605 was associated with early-type ceramics (Liston 1996).

6.3.3. Mangilao

Mangilao, situated in the Huchuano area, Mangilao Municipality, on the eastern shore of Guam, was excavated between 1989 and 1992 by Paul H. Rosendahl Incorporated (PHRI), before a Golf Course established in the area. The Mangilao excavation was extensive, with 49 shovel tests 371 excavation units and 95 backhoe trenches carried out, as well as extensive surface collections. They produced a large amount of data, and laboratory analyses of excavated material including 57 radiocarbon dates, and analysis of 7000 ceramic sherds. Approximately 7100 artefacts and the skeletal remains of at least 143 individuals were found. The excavation revealed that people have been living in the area for a long time, and the earliest evidence of human activity in the Early Pre-Latte Period might be as early as 3600 BP, continuing up to the 17th century (Dilli *et al.* 1998:i).

The Early Pre-Latte Period material is dominated by ceramics, flaked lithic artefacts and shell debitage, but also contains shell and bone fishing gear, ornaments, pestles, needles and scrapers.

6.3.3.1. Ceramics

The excavation at Mangilao recovered thousands of pottery sherds from all periods of Mariana prehistory. Seven thousand of these were analysed and dated to the Early Pre-Latte Period (Stratum IIIg in EU241 through to EU249). PHRI observed that most of the ceramics were thin (4-6 mm) and red-slipped or polished with everted rims, belonging to small vessels with carinated shoulders and either flat or round-bottomed. The sherds were tempered with either calcareous sand (70%) or a mixed sand temper (30%). A few decorated sherds were found with impressed decorations, some with the intricate Achugao décor. The ceramic collection from Mangilao appears fairly typical compared to other ceramic collections in the Marianas, and the ceramics change over time in the same way as on every other reported site in the islands.

6.3.3.2. Lithics

There are numerous artefacts made out of lithics from the Mangilao excavation from the Early Pre-Latte Period. The most common artefact is 'flaked lithics', including use-wear, lithic core, lithic debris, fragments of basalt, and sandstone adzes. The use of lithics increased in the upper layer of the excavation. From the Latte Period, volcanic adzes, chisels, slingstones, net sinkers, pestles and mortars are numerous (Dilli *et al.* 1998:Vol. II)

6.3.3.3. Shell artefacts

Several different types of shell artefacts are recorded including shell beads, pendants, fish hooks and perforated shell. Layers belonging to the Transitional Period produce *Tridacna* shell fragments, *Tridacna* adze preforms, and fragments of adzes, shell fish hooks, and shell gorge fragments. From the Late Transitional Period to the Latte Period layers, harpoon orspear points made out of human and mammal bone, and 17 composite fishhooks were found. The use of shell decreases through time while the use of stone increases (Dilli *et al.* 1998:Vol.II).

6.3.3.4. Other findings

The Mangilao excavation recorded bones from a range of different species: fruit bats, fish species, shark, monitor lizard, and also rat, pig and dog bones, which suggest that the site is heavily disturbed. Although no direct dates are reported from the earliest bones of rat and pig, there is a direct date on an articulated dog skeleton from one of the backhoe trenches dated to AD 1390-1470, which would make it the first and only prehistoric dog to be found in the Mariana Islands (Dilli *et al.* 1998:Vol. III).

6.3.4. Tumon Bay

At Tumon Bay at the west coast of Guam (see Figure 13), a few early sites have been recorded. Radiocarbon dates recorded from a site at Matapang Beach Park area close to the centre of Tumon Bay, excavated by Bath (1986), have yielded extremely early dates. The oldest sample (Beta 14705) is interpreted to derive from a fire-pit deposit, yielded a date of 3880±90 BP, and calibrates to 4040-3990 cal BP. The second oldest date (Beta

14704) is also interpreted to derive from a fire-pit and is dated to 3170±70 BP, calibrated to 3560-3220 cal BP (Bath 1986:30). If the date of 4040-3990 cal BP is correct it would fit within the time range of human arrival suggested by palaeoenvironmental results reported by Athens and Ward (2006). However, both dates from the Matapang excavation are neither in association with a material culture assemblage nor derive from a clearly defined anthropogenic layer. Therefore it is possible that the radiocarbon samples come from ancient tree-moulds rather than fire-pits (Carson 2012) and the ages of the cultural deposits are uncertain.

The Ypao site at the west end of Tumon Bay was excavated in 1978, when construction of recreational facilities at the beach park at Ypao uncovered significant prehistoric deposits.

Several test units were excavated at various locations within the park, but most data is from two 4 x 4 m blocks. Some of the material from the excavation was analysed by Leidemann (1980) and reported in an MA thesis in 1980. Leidemann described pottery of Pre-Latte type, together with other artefacts such as shell beads, stone flakes and fish hooks, but no radiocarbon dating was done (Leidemann 1980; Olmo and Goodman 1994). In 1993, the Ypao site was once again excavated after a ground penetrating radar survey (GPR). Subsequent excavation of five 1 x 1 m units were carried out to locate and identify GPR anomalies. A few sherds of Pre-Latte type were found, and one radiocarbon date associated with them yielded an uncorrected age of 2700±70 years BP (CAMS-7868), calibrated to an age of 2960-2720- cal BP (Olmo and Goodman 1994).

6.3.5. Other possible early sites in Guam

In 1977, Fred Reinman reported an early date from the Nomna Bay site at the east coast of Guam (see Figure 13). He excavated twenty test pits with a varied depth of deposits between 45 cm to 110 cm. The Nomna site was very rich in cultural material, with a large amount of pottery recovered. Most of the pottery found is of Latte age, but a small percentage is a calcareous sand tempered ware of rim A type. Thirteen radiocarbon dates were obtained from the Nomna site, all except two of 'AD' age (Reinman 1977). One outlying early date 3270±170 (GaK 1364) calibrated to 3926-3064 cal BP was obtained in a layer between two much more recent layers. There was no early pottery associated with the date (Reinman 1977; Carson and Kurashina 2012).

The review of the sites above shows a very homogenous material culture whether the site is located on Saipan, Tinian or Guam. These sites also show a very similar material culture to the site in focus for this research, Unai Bapot. All sites contain the same types of pottery, the same types of shell artefacts, and very similar lithic tools and lithic material, although in different abundances at different sites. What is more interesting is that material culture changes at every site as proposed by the different cultural phases (see Chapter 5) at the same time on different islands. This clearly shows that the Mariana Islands, at least in terms of material culture, belonged to the same cultural tradition. The fact that Unai Bapot (which is the best dated site in the Mariana Islands) shares a very similar material culture to Achuago, Unai Chulu, Mangilao and other sites, but is now dated a few centuries younger than these sites, could indicate that these sites are also a few centuries younger than their original radiocarbon interpretations. The difficulties with interpreting radiocarbon dates from the Mariana Islands and Unai Bapot in particular will be discussed in Chapters 7 and 10.

7. The Bapot-1 site

The Bapot-1 site (SP-1-0013) is located at the north end of Laulau Bay (also known as Lao Lao, Magicienne Bay or as Bahia Laolao) on the southeast coast of Saipan Island (Figure 11). The embayment measures ~3 kilometres wide where it opens to the ocean, and is approximately 2.5 kilometres along its seaward-landward axis (Carson 2005). The Laulau Bay reef platform extends to a fringing reef around 100 m from the shore and contains echinoderms (Holothuriidae), marine shellfish (e.g. *Conus* sp., *Cyprea* sp., *Lambis* sp., *Tridacna* sp., *Trochus* sp., *Turbo* sp.) and several species of fish, especially Acanthuridae, Labridae and Scaridae. The archaeological deposits are concentrated on a coastal plain of calcareous beach sand bordered to the north by limestone terraces and outcrops of Pleistocene (Tanapag limestone) and Miocene (Tagpochau limestone) age. The same landform characterises most of the Laulau area (Dickinson 2000). Behind and intruding into the limestones are rocks of the geologically diverse Hagman Formation, containing andesitic breccias, tuff, conglomerate and tuffaceous limestones (Clark *et al.* 2010).

A soil survey of alluvial slope deposits near the Bapot site has defined two categories: 1) Kagman clay, 0 to 0.5% slopes, and 2) Chinen Clay loam 0-5% slopes. Both deposits are considered suitable for general crop growth (Young 1989 in Carson 2005). At present the vegetation at the Bapot-1 site is characterised as mixed forest (*Acacia confusa, Cocos nucifiera, Carica papaya, Barringtonia asiatica*), and large stands of the introduced tangantangan (*Leucaena* sp p.) Rainwater from the low-permeability upland volcanic soil forms small streams that during the wet season transport black volcanic sands to the coast, where they form beach placer deposits (Clark *et al.* 2010).

Saipan Island, Tinian Island and southern Guam Island did not experience tectonic uplift, in contrast to northern Guam Island and Rota Island where observed amounts of emergence exceed hydro-isostatic expectations. This would imply a mid-Holocene tectonic uplift in addition to hydro-isostatic effects. Instead, it is suggested that the coastline on Saipan Island expanded after a post-mid-Holocene drawdown in sea level, estimated at 1.75 m (Dickinson 2000). This sea-level fall is likely to have caused coastal progradation and infilling of sheltered embayments which were colonised by mangroves. Palaeoenviromental research indicates the growth of mangrove habitats in coastal areas of Saipan Island associated with the mid-Holocene highstand (Athens and Ward 2004:47). An effect of the sea-level fall and mangrove stranding was the loss of quiet intertidal settings preferred by the gregarious bivalves *Anadara* cf. *antiquata* and *Gafrarium* sp., which according to archaeological finds, were a popular prehistoric food source used by colonising groups in Remote Oceania (Clark *et al.* 2001; 2010).

7.1. Previous research in the Laulau region

The Laulau area has been of interest to archaeologists since the 1920s, when Hans Hornbostel first examined a rock-art site in a cave at Laulau. Thompson (1932:20) noted: "These drawings are reported to have been executed with white pigment". In 1949, Alexander Spoehr conducted surveys and subsurface investigations in the Laulau region. Spoehr mapped several *latte* sets and excavated a *latte* structure and hearths and possible activity areas associated with the *latte* were found. Furthermore, he excavated a rock shelter containing lime-impressed pottery in the lower layers. In the upper layer, secondary burials and a cremation deposit were revealed (Spoehr 1957:43-58). Spoehr (1957:31) briefly described Laulau and the Bapot site:

"Laulau – There is an extensive village area back of the beach on Magicienne bay. This site was undisturbed by military operations and was partially excavated. Bapot – North and east along the shores of Magicienne Bay there is a coastal terrace about 100 yards wide. The soil is good and there is easy access to reef and offshore fishing. This area is the site of three clusters of latte houses: Bapot I consists of two, Bapot II of four, and Bapot III of five. All have been disturbed by defensive trenching by the Japanese military forces, while a road also cuts across the former occupation area. Sherds are distributed throughout the area. It is probable that the area once contained numerous house sites."

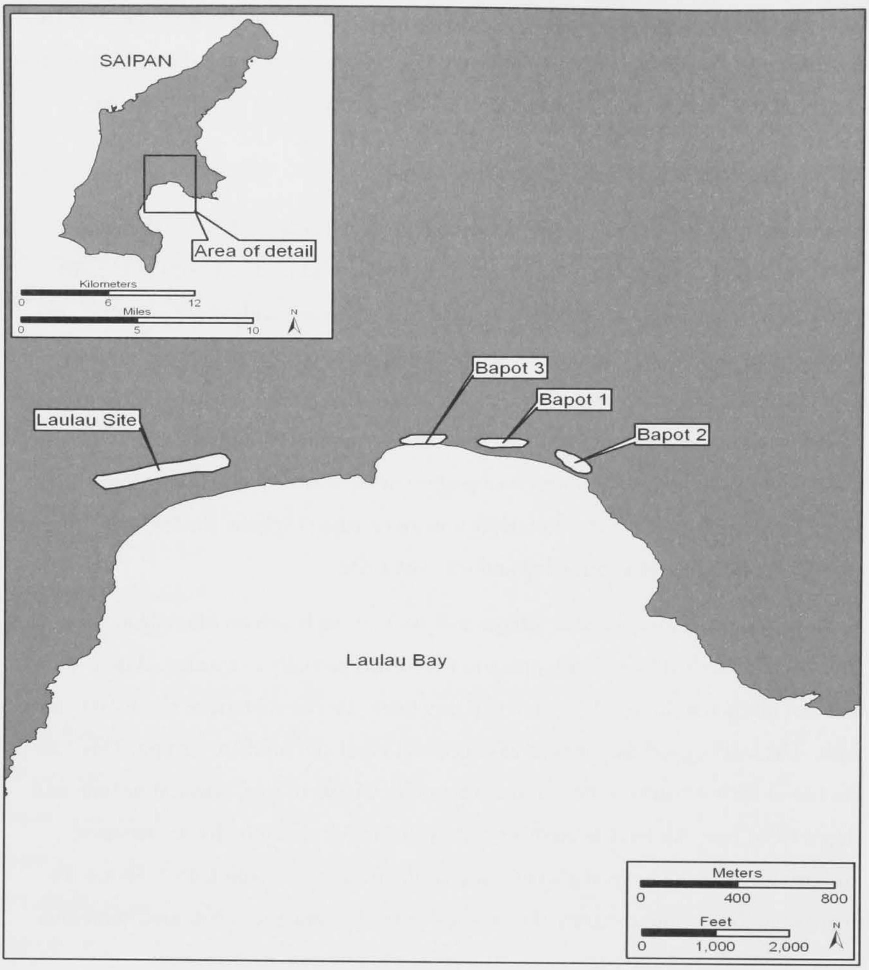


Figure 14. Laulau Bay and location of the Bapot-1 Site (Clark et al. 2010:23 prepared by M Carson).

During the months of April, May and June of 1977, Jeffrey Marck was contracted through the Commonwealth of the Northern Marianas Office of Historic Preservation to test cultural sequences along the northern coastline of Laulau Bay. After initial test pits of 1 x 1 m, which indicated the presence of prehistoric occupation, a main excavation of 3 x 3 m was conducted between two *latte* structures at Bapot 1. The excavation (squares K-M:36-38) was taken down to sterile beach sand at a depth of approximately 2 m (1.9-2.2 m) below the present ground surface (Figure 14). In the interim report from 1978, Marck reported a cultural material assemblage consisting of pottery, stone adze, flakes, shell ornaments and fish hooks. The pottery sequence found at Bapot correlates well with that identified by Spoehr at Chalan Piao and at Laulau rock shelter, starting with carinated red ware jars with everted rims, which gradually became less everted, followed by transitional plain ware associated with tray and bowl vessel forms. Marck concluded that the upper levels only contained Mariana Plain Ware, and the lowermost only Mariana Red Ware, while there was a mixture of both in the middle of the sequence. Marck saw this change in pottery style as a local development, rather than a result of external influences (Clark *et al.* 2010 Marck 1978). Marck gave his major analytical attention to the ceramics from the Bapot excavation and divided them into three groups: Red Ware, Plain Ware and Intermediate Pottery. He showed with tables that Red Ware was found from the lowest level (23) nearly to the top level (5). Plain Ware was found from the middle to the top, and the Intermediate type between levels 14 to five. The highest portion of the 12 000 pieces of pottery excavated in the 3 x 3 m block, derives from levels 22 to 17 (200-150 cm). Of the 20 recorded stone flakes from the excavation, all but four were encountered between level 17 and 15 (150cm-130 cm below surface). The abundance of worked shell and stone were also found from level 22 (200 cm below surface) to level 15, and decreased after that. Two samples of charcoal from the base of the squares K-L: 190-220 cm yielded uncorrected dates of 2890±100 BP and 2910±100 BP (see Table 4) (Marck 1978).

In 1979, Ross Cordy conducted a surface survey of the coastal plains and the stream beds in the Bapot area to examine the settlement pattern. He found evidence of late expansion towards the inland of the island and at least three coastal settlement locals associated with *Latte* structures, but did not excavate an early ceramic deposit (Cordy 1979).

Graeme Ward and John Craib excavated Bapot-1 in 1985 under contract to the Historic Preservation Office of the Commonwealth of the Northern Mariana Islands (CNMI). The investigation aimed to document the surface features and stratigraphy in more detail than previous investigations. In an intensive program of test pitting and excavations, they collected stratigraphic data over a large area and concluded that the site has an area of 12 000 square metres from the southern margins of the coastal plain inland to the elevated limestone ridge. Ward and Craib (Ward 1985) excavated a test pit of 1 x 2 m just south of the 3 x 3 m test trench excavated by Marck in 1977 (Bonhomme and Craib 1987). The excavation was stopped in square S3W12 at a depth of 1.95 m below datum.

Square S4W12 was taken down to 3.6 m below datum. Cultural material (pottery, adzes, flakes, shell, ornaments, and fishhooks) was infrequent below 3 m depth, but occasional marine bivalves and charcoal fragments were reported at 3.5 m depth, unlike in Marck's excavation where no prehistoric material was found below 2.2 m. Six radiocarbon dates from *Anadara antiquata* were obtained for the deposit (Ward 1985; Bonhomme and Craib 1987).

In 1986, additional survey and testing was conducted by Michael Graves in the Bapot-1 area to locate and record archaeological resources. Graves identified significant archaeological sites including previously unrecorded *latte* sets and rock shelters. Further surface surveys were carried out by Richard Olmo in 1992 with 13 different features including four rock shelters, surface scatters of potsherds, and *latte* sets recorded (Carson and Welch 2005; Carson 2008).

In January 2005, the Bapot *latte* site was investigated at the request of the Division of Historic Preservation office (DHP) of the CNMI. The archaeology was undertaken by Mike Carson and David Welch (2005) of International Archaeological Research Institute Inc. (IARII). Investigations involved archival studies, detailed field mapping, limited excavation and laboratory analyses. The primary goal of the project was to update documentation of the site for nomination to the National Register of Historic Places (NRHP).

A surface survey and detailed field mapping of a 500 square metre area were carried out before excavation. A one metre contour map was completed for the project showing the surface cultural remains and artefact scatter in relation to landforms. This map confirmed the arrangement of *latte* remains, terrain contours and locations noted in Ward and Craib's transit map of 1985 (Carson and Welch 2005; Carson 2008). The architectural remains at the Bapot site consist of two clusters of fallen columns and capstones of *latte* structures. They appeared to have been in paired rows, running east-west parallel with the shoreline. The eastern *latte* stones include four paired columns, and the western consist of four or five paired columns. Associated with the *latte* architecture was a broken *lusong* (grinding basin).

Two 1 x 2 m test units (TU-1, TU-2) were excavated down to c.190 cm (TU-1) and 220 cm (TU-2). Both units disclosed a deep stratigraphic sequence of four major zones in seven distinct layers, with small internal variations. The uppermost portion of the units (layer 1-A) show 20th century disturbance, evident in World War II shrapnel, metal and modern bottle glass. The lower portions of the excavations are intact with no eroded potsherds, but small eroded red ware and black ware sherds are found in the upper layers 1-A through to layer III-A in TU-1, and I-A through to the top of layer II-B in TU-2.This indicates some vertical mixing of material between layers. The pottery assemblage from the excavation included 3259 sherds from TU-1 and 5051 sherds from TU-2, and contains sherds of almost all the known ceramic sequences in stratigraphic order, with thin red ware in the lowest layers, and thick and coarse plain ware in the upper layers (Carson and Welsh 2005:26). The early red ware potsherds are from thin-walled vessels with complex shapes, and some straight-sided vessels. A small amount of decorated red/black ware pottery was found in the second-earliest layer (III-C). Two different décor styles were represented, the primary one had very fine dentate impressions and stamping to fill space between incised parallel lines and is the style named as Achuago Incised style by Butler (1994). The second décor with incised circles and lines without dentate impressions is the style named San Roque Incised by Butler (1994). Decorated sherds were also found in the intermediate layers of the excavation (Layers III-A through layer II-a) which included sherds with incised circles, or chevrons on the top of the rim.

7.1.1. Lithics

No complete adzes were found in the excavation, but a small amount of adze material was encountered with two polished chalcedony pieces in layer III-C (155-170 cm) in TU-1 and a piece of an andesite adze fragment in layer III-B (160-180 cm) in TU-2. In TU-1, a chert adze fragment was found in the middle of layer II-B (72-85 cm). A possible slingstone made out of beach rock was recovered from layer III-B (135-145 cm) in TU-1.

A small amount of flaked lithics derived from three different materials; andesite, chalcedony and quartz were recovered from both test units. In TU-1, a total of 429.5 g of flaked material was found. Of these, five flakes of andesite with a total weight of 241 g were found in the uppermost layer. In the lowest layer, nine flakes of chalcedony were discovered with a weight of 42 g. Two quartz flakes were found, one in layer II -B (85-100 cm) and one in layer III-B (135-145 cm). TU-2 shows a similar amount of flaked material as TU-1; a total of 391.8 g of flakes from the same lithic material groups as in TU-1 were found, although a slightly larger amount (14 flakes weighing 87.6 g), including all three lithic material groups, were encountered in the lowest layer. All together, 1089 g of lithic material was recovered from TU-1 and TU-2.

7.1.2. Shell and bone material

The shell and bone material from the Bapot excavation includes spear points, fish hooks and shell ornaments. Three pieces, probably from the same spear point, of carved human bone were found in the upper level of layer II-B (50-60 cm) in TU-1 (Carson and Welsh 2005:35). Only three one-piece fishhooks were encountered, one each from layer I-A (40-43 cm) in TU-1, layer II-B (50-60 cm) in TU-1 and layer II-B (60-80 cm) in TU-2. Fragments of cut and polished nacreous marine shell from layer IV-A (200-220 cm) in TU-2 could indicate fish hook manufacturing during the earliest use of the site. Eight shell beads manufactured of cut and polished *Conus* sp. shell were found, five from TU-1 and three from TU-2, and these occured through the entire sequence, from layer III-C (155-170 cm) through I-A (0/15- 20 cm).

One shell ring was found in the middle of layer II-B (60-72 cm). Two pendants of cut, drilled and polished nacreous marine shell were encountered in layers III-B (160-180 cm) and in III-C (180-200 cm) in TU-2, and one *Anadara* sp. shell pendant was recovered from the same layer. A coral pendant was present in the lowest layer IV-A (200-220 cm) in TU-1.

The 2005 excavation obtained three radiocarbon dates, one on charcoal and two on *Anadara* sp. shell associated with a hearth/burning which indicated occupation at 3500 cal BP (see Chapters 8 and 10).

7.1.3. The 2008 Bapot excavation

The antiquity and richness of the cultural deposits recovered by excavations in the Bapot area, indicate the area's importance during early prehistory. A new excavation, known as Block A took place in April 2008 and consisted of a 3 x 3 m unit. The purpose was to obtain a larger sample of the oldest deposit for material culture and chronological analysis (Clark *et al.* 2010). Block A is located on the 7 m contour between Carson and Welch's test units TU-1 and TU-2, just north of the *latte* remains (Figure 15).

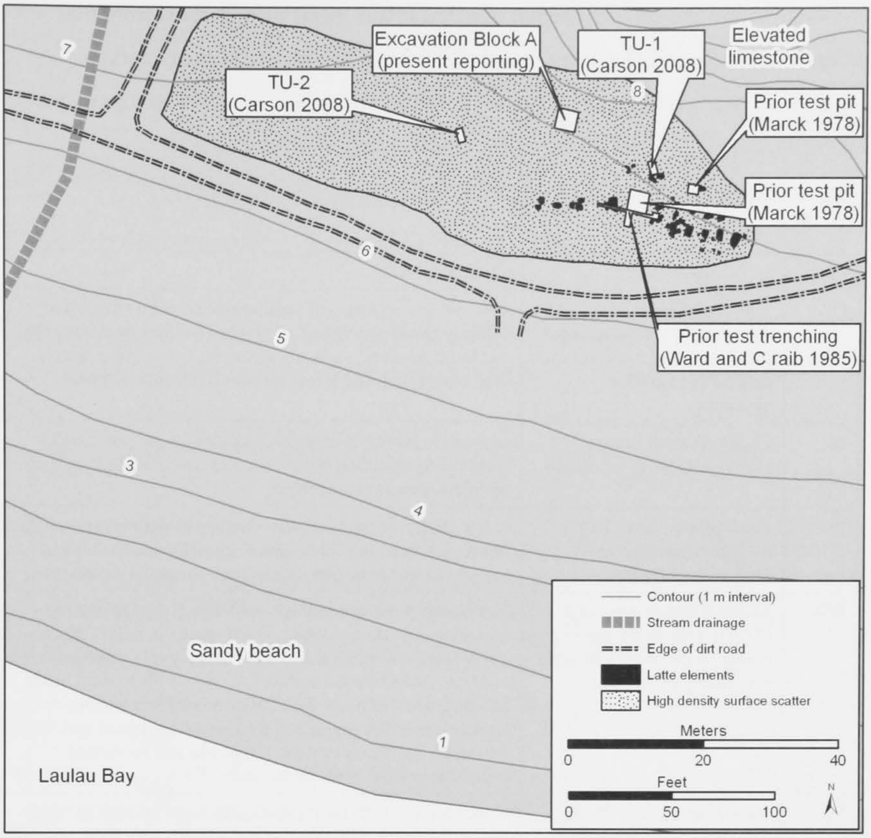


Figure 15. Detailed map of archaeological excavations at Unai Bapot (Clark et al. 2010:23, prepared by M Carson).

The 2008 excavation was carried out by 10 cm levels/spits with the exception of the first 65 cm, where the excavators followed natural layers. Identifying the natural layers proved to be difficult and the excavation protocol was changed to 10 cm levels even within natural layers (see Carson 2014:108). Depth measurements were taken from a datum, a levelled stringline set 23-35 cm above the ground surface which varied in height over the excavation area. For a 2010 paper (Clark *et al.* 2010), the excavation depths were adjusted with a ground level set at 0 cm to allow comparison with previous excavations. In this thesis, all depths are reported as excavated with first level reported as 23-35 cm, and depths referred to as 'cm below datum' (cmbd). All sediment was screened through 2 mm mesh and subsamples from every 10 cm layer were screened through 0.5 mm mesh to ensure small elements were not being lost.

The stratigraphy and soil description reported in this thesis were derived from the author's field notes, PhD student Patrick O'Day's (also one of the excavators) unpublished thesis (2015), and Clark *et al.* (2010). Drawings of all the stratigraphy are included along with details of field plans and features, in Figures 16-36.

Table 3. Description of Stratigraphic layers at Unai Bapot Block A.

Layer	Soil Description	Material Content
I	Very dark brown (10YR 2/2) hard-packed silty calcareous soil containing tree roots and fragments of eroded limestone.	Latte-Period pottery with medium-thick plain sherds and abruptly thickened rims; and small quantities of marine shell and bone. Modern materials included; bottle glass, World War II shrapnel, and a few pieces of vulcanized rubber.
Ia	Dark yellowish brown (10YR 4/4) loose sandy soil.	Latte-style pottery with a few eroded thin red pot sherds, possibly representing older ceramics that have been mixed with late prehistoric ceramics.
II	Light pale-yellow (7.5YR 6/4) loose aeolian beach sand with little silt.	A few sherds of thick-walled red-slipped pottery; sparse chert flakes; marine-shell fragments (especially Turbo sp.) and occasional bones of fish, reptile and mammal (mouse/rat).
III	Medium brown silty sand (7.5YR 4/4). In the lower part (110 cm depth) the sand is partially cemented.	Increasing quantities of thick-walled red-slipped pottery including a dense concentration of sherds in unit 6, along with a few sherds of thin red and black pottery and stone and shell artefacts (basalt-andesite flakes; Tridacna adze, shell beads and fragments of pearl shell (Isognomon) fish hooks). A human burial was found in the southeast corner of unit 9 at 11 cm depth. The remains were left in situ and no further excavations were made in the unit.
IV	Yellowish brown (10YR 5/4) loose silty calcareous sand.	Upper levels of the layer produced a large amount of thick-walled ceramics with red-slip and greyish very thick ceramics from flat based trays. Marianas Redware increased, including a few decorated sherds. Adzes, flakes, small Conus sp. shell rings and ground Cypraea sp. beads are also present.
V	Yellowish brown (10YR 5/6) indurated coarse sand in upper portions of the layer and coarse sand with pockets of indurated sand in the lower portions of the layer.	Thin red-slipped pottery, from small-to medium-diameter carinated jars; in situ base sherds; shell artefacts, and a large sub-lenticular light-grain volcanic adze (20 x 10 cm).
VI	Brown (7.5YR 4/3) silty calcareous sand with areas of indurated sand.	Large quantities of thin red-slipped pottery; shell artefacts; a cache of three adzes made of altered sandstone. Faunal remains including bird and fish bone and marine shell. Abundance of charcoal was found especially in unit 1-2.
VII	Yellowish red (5YR 4/6) indurated silty sand.	Contained similar artefacts as those found in layer VI: red-slipped pottery (some decorated, Achuago Incised and San Roque, shell artefacts, stone artefacts manufactured of altered sandstone and stone flakes from a range of lithic material. Faunal remains with abundant bone from a rail (Gallirallus cf. philippensis). Large charcoal flecks were encountered.
VIII	Very pale brown (10YR 7/4) coarse indurated calcareous sand.	No cultural materials present.

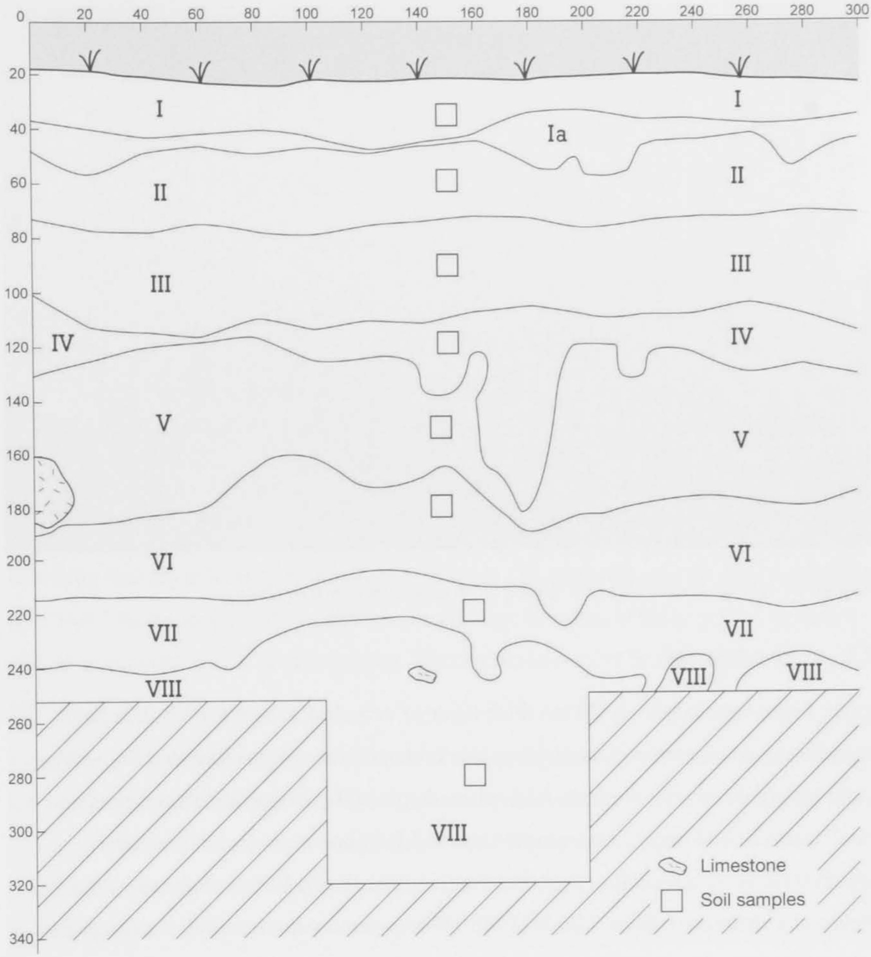


Figure 16. Bapot-1 Block A stratigraphy, north face.

Figure 17. Photograph Bapot-1 Block A stratigraphy, north face.

7.2. Stratigraphy

Layer I is an approximately 20 cm thick layer of very dark brown (10YR 2/2) hard-packed silty calcareous soil, containing tree roots and fragments of eroded limestone. Latte-style pottery with medium-thick plain sherds with abruptly thickened rims and small quantities of fragmented marine shell and fishbone is present in this layer. Material of recent age included modern bottle glass, World War II shrapnel, and a few pieces of vulcanised rubber. Marck (1978:18) recovered American bullet casings from a subsurface fire pit near the Latte remains. Layer I was divided into two sub-layers: I and Ia because of differences in colour and texture, but more so because of the presence of material of recent age.

Layer Ia was comprised of grey (10YR 4/4) loose sandy soil. This layer ranges from 5-23 cm and had an irregular lower boundary. Latte-style pottery was found, along with a few eroded thin red potsherds that might represent older ceramics that have been mixed with late prehistoric ceramics. Finds of bone and shells were also found. No modern artefacts were recovered.

Layer II was comprised of a light pale-yellow (7.5YR 6/4) loose aeolian beach sand layer containing some silt, 20-40 cm thick. A few sherds of thick-walled red-slipped pottery, some sparse chert flakes, marine-shell fragments (especially *Turbo* sp.) and occasional bones of fish, reptile and small mammal (mouse/rat) were found.

Layer III is a medium brown silty sand layer, 20-60 cm thick (7.5YR 4/4). In the lower part (110 cm) the sand was partially cemented. Increasing quantities of thick-walled red-slipped pottery were found, including a dense concentration of sherds in unit 6, along with a few sherds of thin red and black pottery. Stone and shell artefacts like basalt-andesite flakes, a *Tridacna* adze; shell beads and fragments of pearl shell (*Isognomon*) fish hooks, and non-human bone were also found. A human burial was found in the southeast corner of unit 9 at 115 cm below the surface. The remains were left *in situ* and no further excavation was made in the unit.

Layer IV was between 100 cm and 150 cm below datum and consisted of medium brown-yellow (10YR 5/4) silty calcareous sand. The lower boundary of layer IV was irregular and uneven. A portion of the layer extends from 140-190 cm below datum intruding into layer V on the north profile (Figure 16), probably representing a degraded tree root. The upper part of layer IV produced large amounts of thick-walled ceramics (20-55 mm thick) with a heavy red-slip. These were identified as flat-based trays or platters (Figure 29).

From 130-140 cm and below, the amount of thin red-slipped pottery (2-3 mm thick), known locally as 'Marianas Red Ware', increased, including several tool-stamped pieces at 140 cm. Other artefacts included stone adzes and flakes, as well as shell ornaments, (mainly small diameter), *Conus* sp. shell rings, and laterally ground *Cypraea moneta* beads.

Layer V comprised of yellowish-brown partially cemented coarse sand (7.5YR 5/6) in the upper part of the layer, and coarse calcareous sand with pockets of cemented sand at the layer base. Layer V is around 70 cm thick, and ranged between 120-190 cm below datum. Thin red-slipped pottery from small-medium diameter carinated jars (including concentrations of *in situ* base sherds), shell rings and beads, shell fish hook fragments and fish hook blanks, and stone adzes (including a large sub-lenticular volcanic specimen ~20 cm long and 10 cm wide), were found. Flecks of charcoal were common in the sediment, with larger fragments and *in situ* concentrations indicating shallow fire pits or hearths. The spit between 180-190 cm had, compared to the other spits, very low artefact numbers except for shell beads made from *Conus* sp.

Layer VI consisted of dark brown (7.5YR 4/3) silty calcareous sand with areas of cemented sand. Layer VI was situated between 160-230 cm below datum. The layer contained stone artefacts (adzes and flakes) and the southwest corner of unit 7 contained a cache of three adzes made in an altered tuff (Figure 18). The layer also had large quantities of thin red-slipped pottery (some sherds less than 2 mm thick), along with shell artefacts (shell rings,beads and fish hooks). The faunal remains included bones from birds and fish, in association with dispersed shellfish remains of *Anadara* sp.

Figure 18. Cache of adzes, 220-230 cm.

Layer VII comprised of orange-brown (5YR 4/6) hard-packed cemented silty sand at 210-260 below the string level. The basal cultural deposit contained similar artefacts (ceramics and shell ornaments) to those in layer VI. Stone tools were made in a variety of materials (basalt andesite, altered sandstone, chert, quartz/calcite), and faunal remains included abundant bird bone from an extirpated rail (*Gallirallus* cf. *philippensis*). Flecks of charcoal were common in the sediment. The stratigraphic difference between layers

VI and VII was largely due to the orange-red colour of the layer VII sediment, probably caused by incorporation of clay-silts into the calcareous beach sediments, and high levels of anthropogenic burning.

Layer VIII consisted of very pale-yellow coarse calcareous sand (10YR 7/4), which was compact, cemented and devoid of cultural material. In unit 2, a 0.5 x 1 m pit was excavated down to 300 cm without encountering any prehistoric remains.

Figure 19. Showing north profile with 0.5 x 1 m pit excavated down to 3 m depth (Photo Clark 2008).

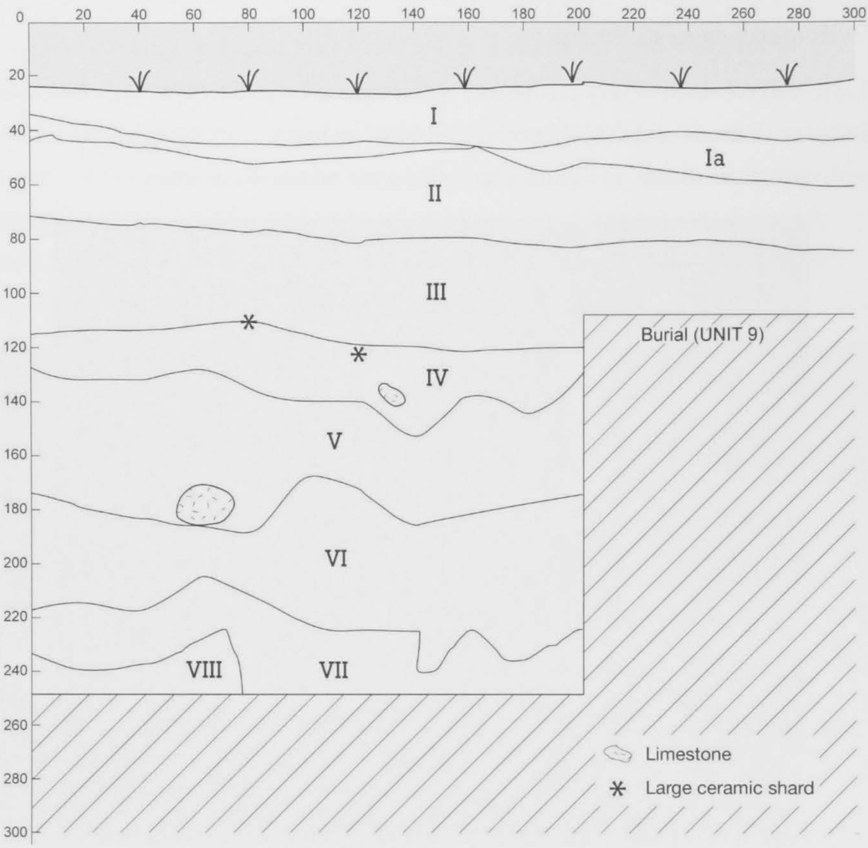


Figure 20. Bapot-1 Block A stratigraphy, east face.

Figure 21. Photograph Bapot-1 Block A stratigraphy, east face.

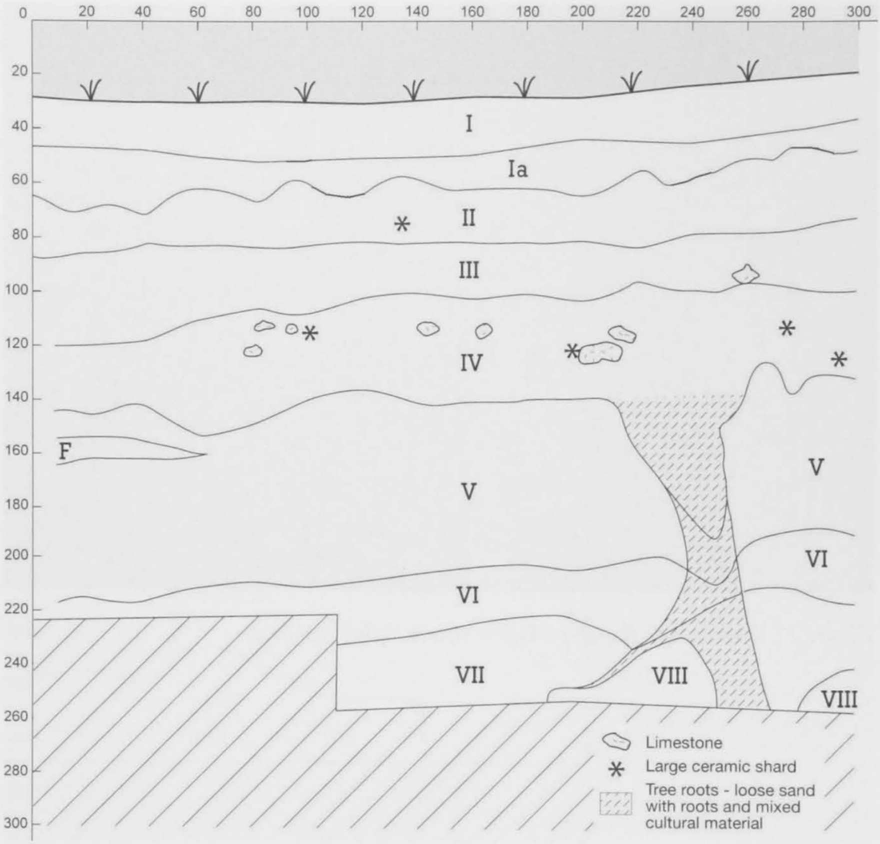


Figure 22. Bapot-1 Block A stratigraphy, west face.

Figure 23. Photograph Bapot-1 Block A stratigraphy, west face.

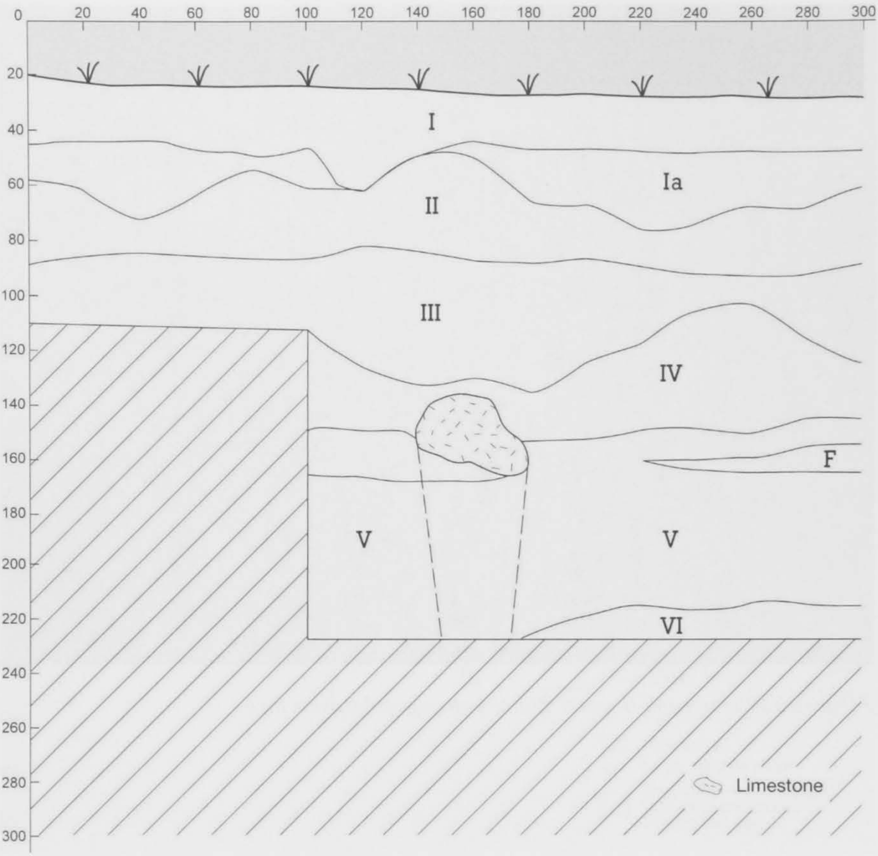


Figure 24. Bapot-1 Block A stratigraphy, south face.

Figure 25. Photograph Bapot-1 Block A stratigraphy, south face.

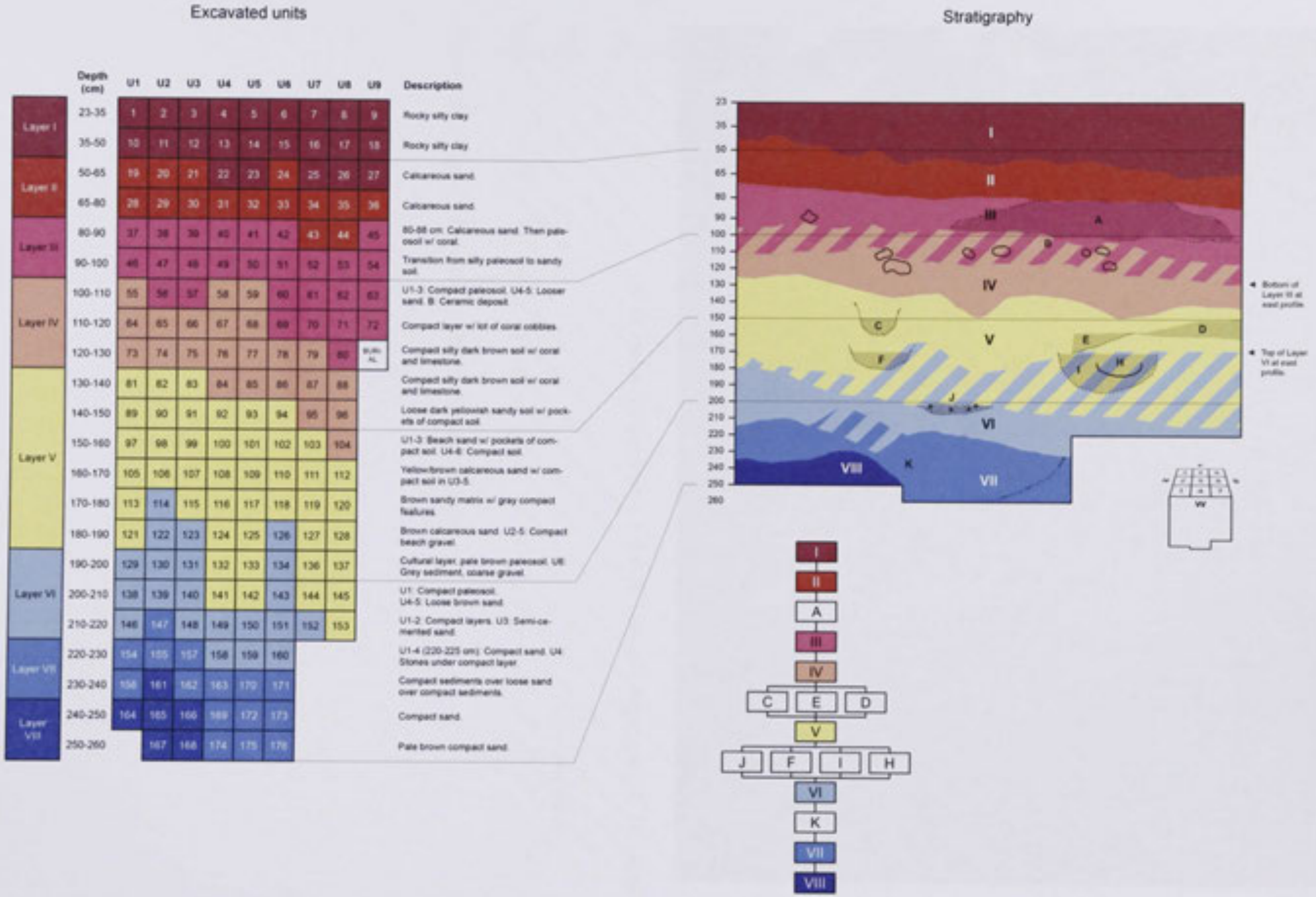


Figure 26. Correlation between stratigraphic layers and excavated units.

7.3. Excavation features

7.3.1. Feature A

Feature A consisted of an oval surface 20 cm thick, containing hard-packed sand with gravels and rocks surrounded by a loose aeolian beach sand layer in units 4, 5, 7 and 8. Some very thick sherds were found on the surface of the feature.

Figure 27. Feature A plan (left); Photo of feature A (right).

Excavation revealed a layer with stones and gravel, and a few thick ceramic sherds were found in the feature.

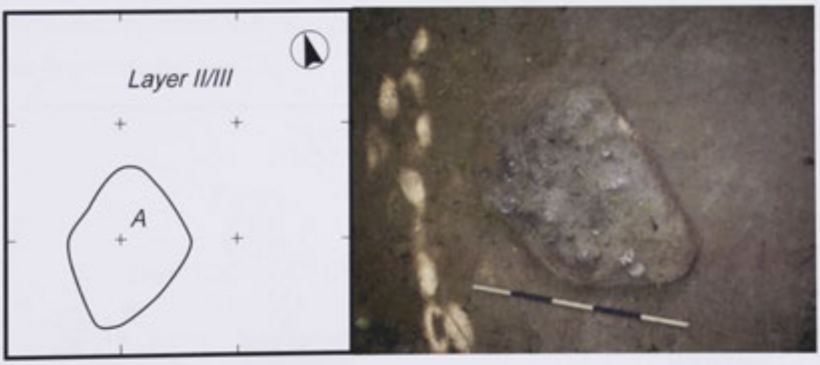


Figure 28. Feature A. Continued excavation of Feature A, in plan (left), and photographed (right).

7.3.2. Feature B

A ceramic deposit in unit 6 at 110-111.5 cm of thick grey/black potsherds from a ceramic tray.

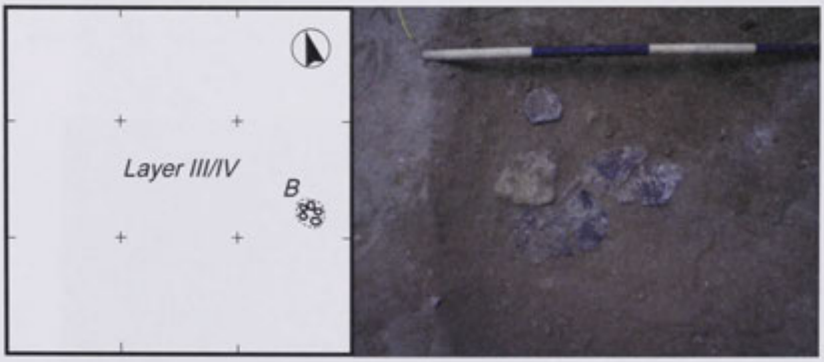


Figure 29. Feature B plan (left); Photo of feature B 110-111.5 cm (right).

7.3.3. Feature C

A pocket of hard packed soil. Not cultural in origin and probably caused by tree growth.

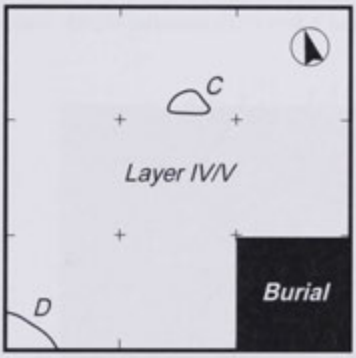


Figure 30. Features C and D plan.

7.3.4. Feature D

Located in the south west corner of unit 7 was a hard-packed sand feature with charcoal flecking and ash. Several thin red pottery sherds were included in the feature matrix, along with a human tooth. Surface elevation was 155 cm and bottom elevation 160 cm. Excavation of feature D showed a thin grey layer of ashy material overlaying a very thin layer of red material. Thin red pottery was found on the surface, but no artefacts were found in the matrix of feature D.

7.3.5. Feature E

Consisting of a very pale brown sand layer at 160 cm, associated with thin red-slipped ceramic sherds, marine shells and charcoal.

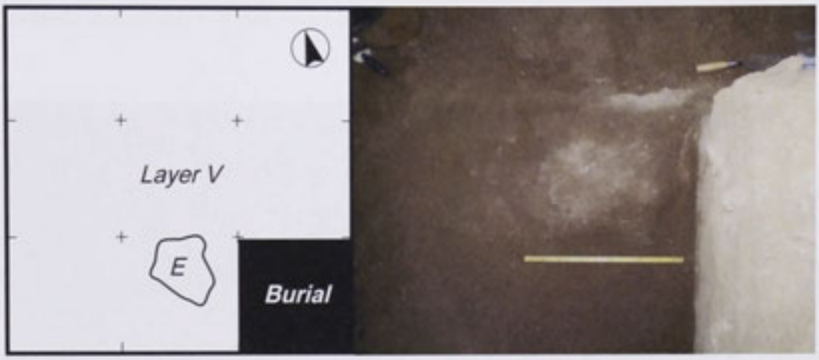


Figure 31. Feature E plan (left); Photo of feature E (right).

7.3.6. Feature F

Feature F consisted of a very hard-packed pocket of grey soil containing small fragments of charcoal and red-slipped pottery. Very coarse beach rubble was found in the grey-cemented sand.

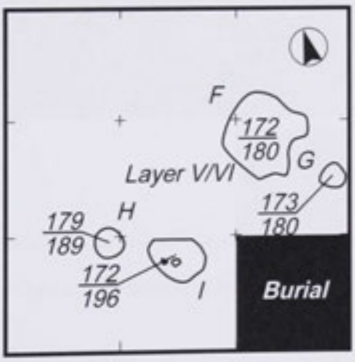


Figure 32. Features F, G, H and I.

7.3.7. Feature G

Compact yellow-brown medium sand in circular pattern. No charcoal or pottery was found in the matrix. Excavation suggested it might represent a posthole or tree root. See Figure 32.

7.3.8. Feature H

Feature H is a red-slipped ceramic pot with out-curved rim. Only the rim-orifice section was found.

Figure 33. Photo of feature H. Plan diagram in Figure 32.

7.3.9. Feature I

In the northeast corner of unit 8 and projecting into unit 5, a feature of light grey cemented layer with large amounts of charcoal, and some ceramics was excavated at 190 cm. The charcoal was collected for radiocarbon dating.

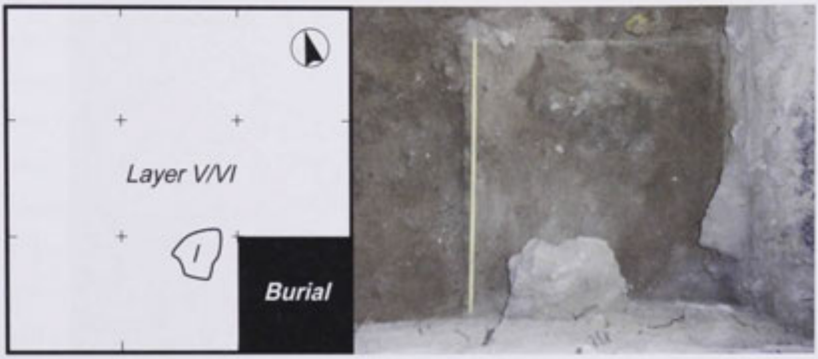


Figure 34. Feature I plan (left); Photo of feature I (right).

7.3.10. Feature J

Feature J was at 200 CMBD and was a mixed beach sand-gravel, light brown in colour. Two very thin potsherds were recovered as well as several good samples of charcoal.

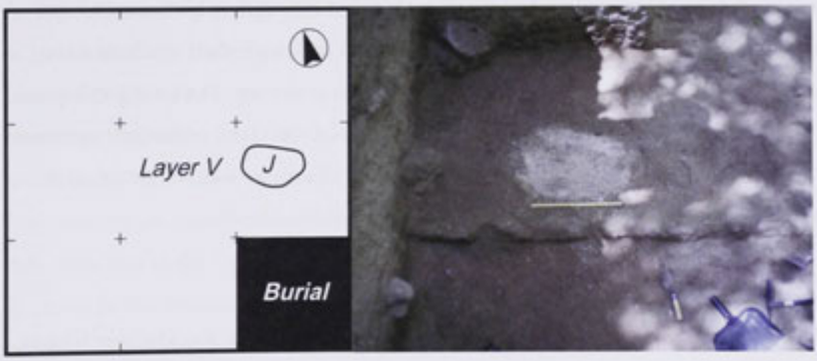


Figure 35. Feature J plan (left); Photo of feature J (right).

7.3.11. Feature K

Feature K consisted of grey compact sediments overlying loose sand below semi-concreted sand. Some red-thin sherds and shell beads were recovered near the top of the feature.

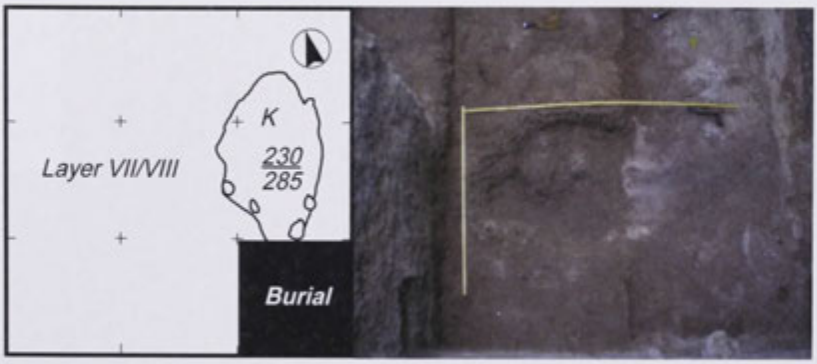


Figure 36. Feature K plan (left); Photo of feature K (right).

7.4. Summary

The cultural material found in the 2008 excavation at Bapot-1 was plentiful, and occurred throughout the stratigraphy, indicating that human occupation and use of the Bapot site has taken place over millennia. Except for an occupation hiatus at 180-190 cm where there was less pottery, lithics and food shell (although shell artefacts were common) the cultural deposit is dense from the bottom to the top. The youngest layer is somewhat disturbed with older thin red pot sherds mixed with later prehistoric ceramics. The following section reviews the radiocarbon dating of the site with the description and analysis of ceramics and other remains following in Section 7.6.

7.5. Radiocarbon dating

Recent work suggests that Unai Bapot is not only the oldest site in the Mariana Islands, but also in the whole of Remote Oceania. First settlement of the Marianas has been suggested to have taken place somewhere between 3600-3500 cal BP, which is several centuries earlier than other parts of Remote Oceanic such as Palau in Western Micronesia and Lapita sites in the Bismarck Archipelago (Carson 2008; Carson and Kurashina 2012; Carson 2014).

The 2008 excavation of the Bapot site produced an initial set of twenty dating samples from Block A (See Table 4), which were analysed at The Waikato Radiocarbon Dating Laboratory in New Zealand. The samples included unidentified charcoal, pieces of charred coconut shell (*Cocos nucifiera*), marine shell artefacts of *Cyprea* sp. and *Conus* sp. and one *Anadara antiquata* shell presumed to be food refuse. As mentioned previously (Chapter 7.1.3) sample depths had previously been reported by subtracting 20 cm to allow comparison of samples dated in previous excavations at Unai Bapot. This chapter reports all excavation depths from the string line datum which was ~23 cm above ground level. Following Clark *et al.* (2010:26) two radiocarbon analyses were considered to be inaccurate and are discussed below. These were Wk-25210 from layer VII at 250-260 cm depth, dated to 3610-3150 cal BP, and Wk-23753 from layer IV 120-130 cm, dated to 2680-2340 cal BP. Sample Wk-25210 is an *Anadara antiquata* shell and we suspect it was either an older naturally deposited shell or that it is an unreliable age. As discussed below, the oldest ages in the Marianas are on *A. antiquata* and marine taxa, while terrestrial carbon samples from similar layers give younger ages. This suggests that marine determinations might not provide a reliable age of human colonisation.

The Block A excavation did not reveal any material-cultural or stratigraphic evidence of an older intact cultural deposit that would support the Wk-25210 age, and the age result is an outlier when compared with other determinations from the same depth. It is worth noting that there are numerous *Anadara* shells that have been deposited naturally on the beach just east of the excavation. As the first people to use the Bapot area inhabited the beach area, it is feasible that some naturally deposited shell of older age was inadvertently included with midden remains. An alternative is that some marine taxa date older due to the hardwater effect, and this is feasible in the Marianas where fractures in the limestone islands can result in the coastal discharge of freshwater that contains limestone-derived 'old' carbon.

Sample Wk-23753 was from unit 7, which contained evidence of a large disturbance, possibly an old tree root or a pit feature which may have displaced the charcoal sample yielding an old age from a relatively shallow context.

In Table 4 it is clear that the upper 100 cm of the excavation is younger than 2000 BP, with lower deposits between 120-160 cm dated ~2300-2060 cal BP at 95.4% probability (combined dates from three unidentified charcoal samples). The deposits from 170-230 cm date older, to ~3100-2960 cal BP, while samples from basal cultural levels 230-260 cm date to 3200-3100 cal BP.

Clark *et al.* (2010) note considerable variability in the ages, particularly between charcoal and marine shell determinations that could be attributed to either sample specific effects like charcoal inbuilt age, shell dietary habits, marine reservoir variability, or from heirloom use. Although no obvious stratigraphic disturbance was recorded during the excavation (except as noted in Section West) it is probable that minor mixing of sediments has taken place from human activities and natural events as is common in other coastal sites in the Pacific.

One of the important issues for Clark *et al.* (2010) was to calculate a marine reservoir correction factor, commonly known as a ΔR for the calibration of marine shell results. The marine ΔR is the difference between the global average modelled marine reservoir and the actual 14C activity of the surface ocean at a particular location (Stuiver *et al.* 1986). A regional ΔR is necessary to accurate calibrate shell, since the 14C reservoir is influenced by local variations in upwelling, ocean currents and climate, as well as by the habitat and dietary preferences of different shell species (Tanaka *et al.* 1986; Hogg *et al.* 1998). One of the methods for determining ΔR is to obtain and compare radiocarbon ages on short lived terrestrial species (charcoal) and marine (food shells) from the same context, which are frequently referred to as marine shell/charcoal pairs (Clark *et al.* 2010:26).

From Bapot-1, samples were identified by Fiona Petchey to short-lived nut shell or as unidentified charcoal, and only three samples were identified to short-lived nutshell charcoal (Wk-23750, Wk-23751 and Wk-23763).The only charcoal sample from below 170 cm is Wk-23763 (220-230 cm). Of the four shell dates associated with the earliest period 170-250 cm (ANU-4768, Wk-23769, Wk-23770), only sample ANU-4768 (from an earlier excavation by Ward and Graves) is an *Anadara* sp. considered to be a food shell. The other two marine shell ages are on shell artefacts made from the carnivorous *Cypraea* sp. (Wk-23769 and Wk-23770). These two shell artefacts were from a shell ornament type that was only present below 230 cm depth (see Appendix 3). Sample (Wk-23771) is a *Conus* sp. shell ring found in the deepest cultural deposits (240-250 cm).

By pairing the nutshell charcoal (Wk-23763) and *A. antiquata* shell (ANU-4768) a ΔR value of -16±87 14C years was calculated for the cultural deposit between 170 and 240 cm depth. The combined value for all charcoal samples from this deposit were indistinguishable, indicating minimal inbuilt age for the unidentified samples. All marine shell determinations were calibrated using the ΔR of -16±87 years.

Even with a calculated ΔR, the calibrated shell dates gave ages which were significantly older by ~200 years than the calibrated charcoal ages. Either the marine shell ages are reliable and the Bapot site dates to 3600-3500 years cal BP, or the charcoal results provide an accurate indicator of site age which is dated to 3200-3100 years cal BP.

To examine this issue further, the Bapot 1 excavators recently submitted 21 new dating samples from the lowest cultural levels of the site. The new samples consisted of three identified charcoal specimens (nut endocarp, twig), one bird bone identified to an extirpated *Gallirallus*, most likely *Gallirallus* cf. *philippensis* (Trevor Worthy, personal communication with Geoffrey Clark, 2009), seven *A. antiquata* shells and ten shell artefacts of different species. It is important to note that all the charcoal, shell artefacts, and bird bone samples were from the same depth and units as the *A. antiquata* shells, and indeed in several cases came from the same feature. The new determinations will be published elsewhere but, here it is important to note that the identified charcoal-bird bone and shell-artefact ages were all essentially identical to the charcoal results published in Clark *et al.* (2010), while the *A. antiquata* ages are consistently older by 100-200 years. The available data clearly indicate that the Unai Bapot sites dates to 3200-3100 cal BP and that the use of some types of marine taxa to date human colonisation of the Marianas does not provide reliable dates of human activity.

In previous work, Unai Bapot has been interpreted as the oldest site in the Mariana Islands with human arrival dated to 1610-1560 B.C. or 3560-3510 cal BP (Carson and Kurashina 2012: Carson 2014). Not only does this age range make Unai Bapot the oldest site in the Marianas with a date of 3600 cal BP, it would also be the oldest site anywhere in Remote Oceania. This conclusion is particularly significant because the Marianas are more than 2000 kilometres from the landmasses of the western Pacific rim, and open ocean voyages of such length did not occur anywhere in the Pacific until the much later colonisation of East Polynesia. In other words, if Unai Bapot dates to 3600 cal BP, it suggests that the first island to be colonised in Remote Oceania was also the most distant in comparison to all other islands colonised between 4000-3000 cal BP in Island Southeast Asia and the Pacific.

The colonisation age of 3600 cal BP was calculated by combining three *A. antiquata* shell dates. Two of the shell samples were from Carson's 2005 excavation at Unai Bapot (Beta-202722, 3680-3390 cal BP and Beta-216616, 3860-3510 cal BP), both from the same discard pile at 200-220 cm depth in Test unit 2 (TU-2). The third shell was from the 2008 excavation (Wk-25210, calibrated to 3560-3300 cal BP; Carson 2014: Table 4.1). Both of the Beta determinations were rejected by Clark *et al.* (2010) as they appeared to be on burned *Anadara* shell. There is evidence from cremated bone experiments (Hüls *et al*. 2010:596) that recommends caution when dealing with samples that may have been burnt in contact with limestone substrates (in this case lime sand), which could produce an "old wood" effect. An additional source of concern is that the two dated *Anadara* sp. shells from the same "localised discard" feature have Conventional Radiocarbon Ages that differ from one another by 110 radiocarbon years, which supports the view that there is significant variability in *Anadara* sp. age results. Carson (2014) uses the oldest calibrated age for Wk-25210, but the date was rejected by the excavators, since there was no firm association with cultural activity and charcoal from the same depth is substantially younger (Clark *et al.* 2010: O'Day unpublished thesis 2015).

By combining the earliest part of the age range of sample Wk-25210, which is calibrated to 3560 cal BP (1610 BC) with the youngest end of sample Beta-216616, calibrated to 3510 cal BP (1560 BC), Carson constructs an artificial "Best Date Range" of 3560-3510 cal BP or 1610-1560 B.C., which also overlaps with Carson's sample (Beta-202722), calibrated to 3680-3390 cal BP (1730-1440 BC.). The overlap of radiocarbon dates is common in archaeology, but it is statistically wrong to take the two middle age values (median intercept ages) rather than using the full date range, which would be 3860-3300 cal BP or 1920-1340 cal BC (95.4% probability) if using the two samples Wk-25210 and Beta-216616. The "Best Date Range" calculated is clearly highly selective and was made to support a hypothesis of human arrival in the Marianas at 3600-3500 cal BP. It appears unlikely that dates on *Anadara* are accurate. It is also unlikely that the molluscs were deposited by people in the interval 3560-3510 BP (see also Cochrane 2014:116).

The 2005 excavation of Unai Bapot failed to find any charcoal deeper than 140-160 cm, and Carson speculated that charcoal did not preserve within deeper layers of unstable beach zone, meaning that charcoal found deeper than 160 cm had drifted downward through the sandy matrix (Carson 2014:40). However, in the first report prepared for the Commonwealth of the Northern Mariana Islands Division of Historic Preservation Office, Carson and Welch (2005) state that they collected charcoal from all layers including Layer IV-I: 200-220 cm, which was the deepest layer with cultural material (Table 2 and 3). They report: "The total amount of charcoal in tables 2 and 3 refers to the individual flecks and chunks of charcoal retrieved from point-plotted contexts in discrete subsurface features. Additional pieces of charcoal were noted but not collected during the excavations. The subsurface features included in situ combustion features and localised discard piles." (Carson and Welch 2005:44).

One probable reason for the small amount of charcoal found in the 2005 test units, was the excavation method used. The excavators reported use of a pick and shovel at lower depths with sediments screened with ¼ inch mesh (Carson and Welch 2005:5). This excavation technique likely resulted in a failure to recover small and fragile items including charcoal, bone fragments and small shell ornaments that were common in the 2008 excavation, which employed 2 mm mesh.

The 2008 excavation recorded *in situ* charcoal in all cultural levels, with evidence that much of the charcoal derived from shallow fire pits/hearths or the remains of deeper pit features that had been eroded. The excavations did not reveal any evidence for site disturbance from the sea that might have removed charcoal from the site by flotation, such as water-rolled ceramics, displaced/eroded cultural material, or layers of marine deposited sediments. Indeed, some charcoal was recovered from beneath *in situ* concentrations of ceramic sherds, suggesting that charcoal must been displaced downward and then horizontally below pot sherds if Carson's (2014) hypothesis about the presence and mobility of charcoal in the lower layers of the Bapot site are correct.

As discussed, the results of redating the Bapot site show that the age of the oldest deposit is most likely 3200-3100 cal BP, and that *A. antiquata* must be used very cautiously when dating archaeological sites on limestone islands in the Marianas. It is significant that bird bone, non-*Anadara* sp. shell artefacts, and identified short-lived charcoal samples from the lowest cultural deposit of Bapot have virtually the same calibrated age, indicating that it is unlikely that site disturbance is responsible for the older shell results. This is especially relevant when there is no evidence that older charcoal was removed by sea flotation, nor that younger charcoal has permeated downward from overlying levels. This conclusion is strongly supported by photographs of the 2008 site stratigraphy which clearly show that the basal culture deposits in layer VII had an orangey-brown colour from high levels of anthropogenic burning, with charcoal stained patches visible in the section, and shallow fire pit hearths recorded in plans.

The 2008 radiocarbon results on charcoal also fit well with the results of Marck's 1977 excavation, where charcoal was found and collected all the way through the excavation even though he was using simple excavation methods such as 1/4 inch mesh. Marck dated two charcoal samples collected from an earth oven at a depth of 190-220 cm (UCR 649) and (UCR-650) (Marck 1978:63). The samples have large standard errors giving them a wide age range of 3330-2790 cal BP (UCR-649) and 3340-2800 cal BP. The dates have a slightly older span as they extend toward 3400 cal BP due to the large standard errors, but they are relatively consistent with ages on charcoal recovered from comparable depths in the 2008 excavation.

To conclude, it seems likely that Unai Bapot does not date to 3600 cal BP as claimed, and is younger with an age of 3200-3100 cal BP. This suggests that the Marianas were colonised more recently than has been claimed by many researchers over more than 30 years who estimated human arrival at 3500 cal BP. The implications of a more recent date for human occupation of the Marianas is discussed in relation to alternative models of colonisation of Remote Oceania in Chapter 10.

Table 4. Bapot-1 site radiocarbon dates.

Lab. No.	CRA	$^{\delta}$13C (±0.2‰)	cal BP (95.4% probability)	Sample	Unit, Depth (cmbd)
Wk-23750	1386±30	-22.6±0.2	1345-1276	Coconut shell	Unit 8, 50-60
Wk-23751	1581±35	-23.4±0.2	1547-1397	Nut shell cf. Cocos nucifera	Unit 4, 70-80
Wk-23752	2043±30	-24.3±0.2	2113-1925	Unidentified charcoal	Unit 2, 90-100
Wk-23754	2189±30	-24.5±0.2	2309-2127	Unidentified charcoal	Unit 2, 120-130
Wk-23755	2168±32	-27.9±02	2309-2062	Unidentified charcoal	Unit 8, 150-160
Wk-23756	2175±30	-25.7±0.2	2309-2071	Unidentified charcoal	Unit 5, 150-160
Wk-23757	2907±32	-25.1±0.2	3157-2957	Unidentified charcoal	Unit 7, 170-180
Wk-23760	2866±32	-25.3±0.2	3076-2875	Unidentified charcoal	Unit 5, 200-210
Wk-23761	2922±30	-24.6±0.2	3161-2971	Unidentified charcoal	Unit 8, 210-220
Wk-23763	2904±30	-21.8±0.2	3156-2956	Nut Shell	Unit 2, 220-230
Wk-23764	2910±30	-25.1±0.2	3157-2961	Unidentified charcoal	Unit 2, 230-240
Wk-23765	2900±30	-25.5±0.2	3156-2953	Unidentified charcoal	Unit 2, 230-240
Wk-23769	3355±30	1.9±0.2	3422-2969	Cypraea sp. artefact (Herbivore)	Unit 1, 230-240
Wk-23770	3192±30	2.1±0.2	3251-2774	Cypraea tigris artefact (Herbivore)	Unit 1, 230-240
Wk-23766	3013±30	-25.5±0.2	3336-3078	Unidentified charcoal	Unit 5, 240-250
Wk-23771	3182±30	0.6±0.2	3236-2767	Conus sp. artefact (Carnivore)	Unit 4, 240-250
Wk-23767	3010±30	-28.1±0.2	3334-3077	Unidentified charcoal	Unit 1, 250-260
Wk-23768	2908±30	-24.9±0.2	3156-2960	Unidentified charcoal	Unit 4, 250-260
Wk-23753*	2386±30	-25.9±0.2	2676-2344	Unidentified charcoal	Unit 7, 120-130
Wk-23210*	3484±35	-0.7±0.2	3608-3149	Anadara sp. Filter feeder	Unit 2, 250-260

* Rejected dates

Table 5. Bapot-1 ΔR results for contemporaneous charcoal/shell (Clark et al. 2010).

Sample material	^{14}C age and error (BP) [Rs(t)]	Pooled values (χ^2 test)	Marine modelled age [Rg(t)]	ΔR (yrs) [Rs(t) - [Rg(t)]**	Lab. number	Comment
ΔR calculations for deposits above 220cm						
Nutshell charcoal	2904 ± 30	-	3226 ± 33	-16 ± 87	Wk-23763	Meets ΔR protocol
Anadara sp.	3210 ± 80	-	-		ANU-4768	
Cyprea sp. (artefact)	3355 ± 30	-	-	129 ± 45	Wk-23769	Possible heirloom or dietary offset ?
Cyprea sp. (artefact)	3192 ± 30	-	-	-34 ± 45	Wk-23770	Possible heirloom or dietary offset ?
ΔR calculations for deposits below 220cm						
Unid. charcoal	3010 ± 30	3012 ± 21 ($\chi^2_{2:0.05}$ = $0.01<3.84$)	3345± 37	-162 ± 47	Wk-23767	Inbuilt age ?
Unid. charcoal	3013 ± 30				Wk-23766	
Conus sp.	3182 ± 30	-	-		Wk-23771	
or						
Unid. charcoal	2908 ± 30	-	3196± 63	-13± 70	Wk-23768	Inbuilt age ?
Conus sp.	3182 ± 30	-	-		Wk-23771	

**The ΔR for a specific location "(s)" is calculated using the formula: Rs(t) – Rg(t) = ΔR(s), where (ΔR(s)) is the difference between the global average (Rg(t)) and the actual ^{14}C activity of the surface ocean at a particular location (Rs(t)) at that time. (Stuiver et al. 1986). ΔR calculations from archaeological terrestrial/marine pairs as per Ulm (2002).

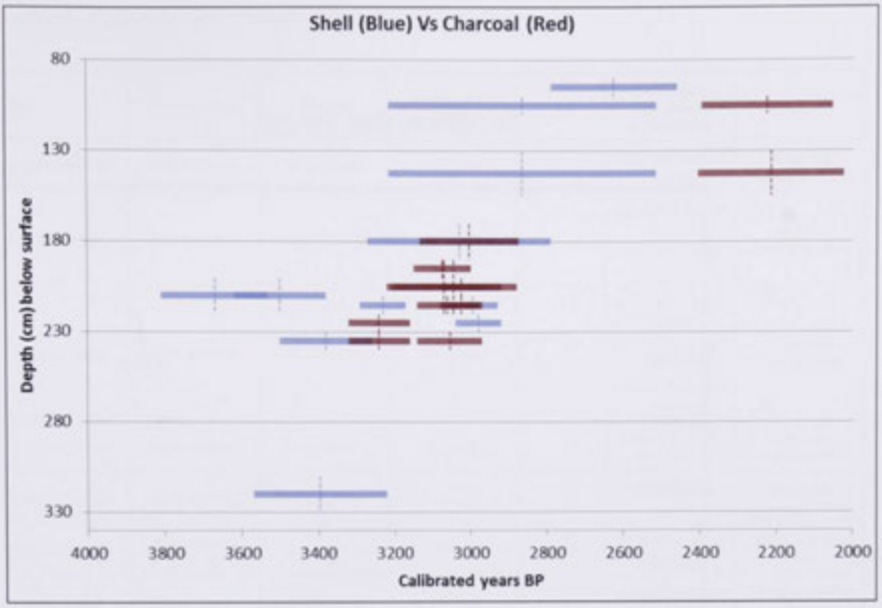


Figure 37. Chart of all reported shell dates from Unai Bapot and charcoal samples from the same depth all reported at 68.2% cal BP as in (Clark et al. 2010:27). Note that marine shell determinations are older than results on unidentified charcoal.

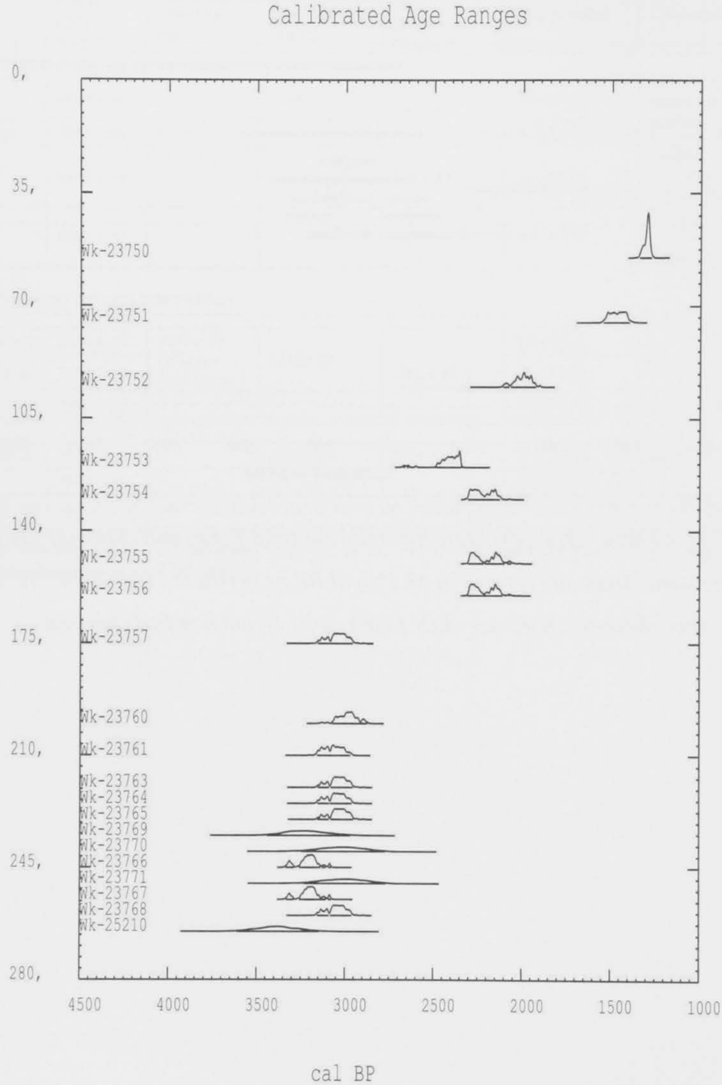


Figure 38. Date plot of Unai Bapot Cal BP (95.4% probability)

Table 6. Palaeoenvironmental data.

Site	**Dated material**	**Sample**	**Radio-carbon Age**	**Δ R**	**Two Sigma Range and relative area**	**Reference**
Kagman, Saipan	Bulk sediment	Beta-123089	7110±50		8015-7841 cal BP (1.000)	Dega and Cleghorn 2003
Kagman, Saipan	Bulk sediment	Beta-123090	4250±70		4973-4571 cal BP (0.997) 5027-5022 cal BP (0.003)	Dega and Cleghorn 2003
Kagman, Saipan	Bulk sediment	Beta-123091	3710±50		4160-3903 cal BP (0.963) 4177-4171 cal BP (0.006) 4226-4200 cal BP (0.031)	Dega and Cleghorn 2003
Kagman, Saipan	Bulk sediment	Beta-123092	1630±40		1610-1412 cal BP (1.000)	Dega and Cleghorn 2003
Kagman, Saipan	Bulk sediment	Beta-123094	780±50		791-657 cal BP (1.000)	Dega and Cleghorn 2003
Susupe, Saipan	Veremolpa sp. marine shell	Beta-186316	3050±40	-16±87	3122-2672 cal BP (1.000)	Athens and Ward 2006
Susupe, Saipan	Bulk sediment	Wk-12148	2690±43		2866-2747 cal BP (1.000)	Athens and Ward 2006
Susupe, Saipan	Tellina sp. marine shell	Wk-12149	2759±50	-16±87	2741-2287 cal BP (1.000)	Athens and Ward 2006
Susupe, Saipan	Veremolpa sp. marine shell	Wk-12150	4497±44	-16±87	4933-4429 cal BP (1.000)	Athens and Ward 2006
Susupe, Saipan	Bulk sediment	Wk-12151	6810±49		7732-7576 cal BP (1.000)	Athens and Ward 2006
Susupe, Saipan	Leaf fragments	Wk-12152	7024±49		7954-7742 cal BP (1.000)	Athens and Ward 2006
Susupe, Saipan	Veremolpa sp. marine shell	Wk-12846	3849±57	-16±87	4118-3560 cal BP (1.000)	Athens and Ward 2006
Susupe, Saipan	Veremolpa sp. marine shell	Wk-13638	2967±50	-16±87	3008-2467 cal BP (1.000)	Athens and Ward 2006
Kagman, Saipan	Bulk sediment	Beta-123093	1680±40		1453-1445 cal BP (0.006) 1704-1522 cal BP (0.994)	Dega and Cleghorn 2003
Hagoi, Tinian		ETH-14005	1030±50		870-798 cal BP (0.156) 1057-898 cal BP (0.844)	Athens and Ward 1998
Hagoi, Tinian		ETH-14006	1640±50		1629-1407 cal BP (0.957) 1692-1666 cal BP (0.043)	Athens and Ward 1998
Hagoi, Tinian		ETH-14007	1830±60		1892-1610 cal BP (1.000)	Athens and Ward 1998
Hagoi, Tinian	Wood	ETH-14008	6890±70		7859-7596 cal BP (0.983) 7919-7903 cal BP (0.017)	Athens and Ward 1998
Hagoi, Tinian		Wk-3665	1400±120		1553-1059 cal BP (1.000)	Athens and Ward 1998

Site	Dated material	Sample	Radio-carbon Age	Δ R	Two Sigma Range and relative area	Reference
Hagoi, Tinian	Bulk sediment	Wk-3666	3200±80		3608-3226 cal BP (1.000)	Athens and Ward 1998
Hagoi, Tinian	Bulk sediment	Wk-3667	4610±110		5020-4974 cal BP (0.034) 5586-5028 cal BP (0.966)	Athens and Ward 1998
Hagoi, Tinian	Bulk sediment	Wk-3668	6050±110		7178-6657 cal BP (0.990) 7238-7216 cal BP (0.010)	Athens and Ward 1998
Hagoi, Tinian	Bulk sediment	Wk-3669	6250±70		7315-6970 cal BP (1.000)	Athens and Ward 1998
Hagoi, Tinian	Bulk sediment	Wk-3670	6860±60		7802-7589 cal BP (0.970) 7825-7805 cal BP (0.030)	Athens and Ward 1998
Hagatna Marsh, Guam	Bulk sediment	Beta-27379	3040±140		3513-2867 cal BP (0.984) 3559-3525 cal BP (0.016)	Hunter-Anderson 1989
Hagatna Marsh, Guam	Bulk sediment	Beta-27380	2890±90		3249-2792 cal BP (0.989) 3322-3306 cal BP (0.011)	Hunter-Anderson 1989
Hagatna Marsh, Guam	Bulk sediment	Beta-28033	1300±50		1113-1084 cal BP (0.037) 1160-1120 cal BP (0.050) 1304-1172 cal BP (0.913)	Hunter-Anderson 1989
Laguas, Guam	Bulk sediment	Wk-6995	1804±59		1583-1571 cal BP (0.013) 1871-1598 cal BP (0.987)	Athens and Ward 1999
Laguas, Guam	Bulk sediment	Wk-6996	2441±63		2711-2354 cal BP (1.000)	Athens and Ward 1999
Laguas, Guam	Bulk sediment	Wk-6997	2583±56		2793-2486 cal BP (0.995) 2839-2829 cal BP (0.005)	Athens and Ward 1999
Laguas, Guam	Bulk sediment	Wk-6998	3372±56		3725-3460 cal BP (0.964) 3761-3752 cal BP (0.007) 3820-3794 cal BP (0.028)	Athens and Ward 1999
Laguas, Guam	Bulk sediment	Wk-6999	4020±56		4327-4298 cal BP (0.017) 4369-4353 cal BP (0.010) 4648-4386 cal BP (0.896) 4698-4672 cal BP (0.018) 4806-4759 cal BP (0.059)	Athens and Ward 1999

Site	Dated material	Sample	Radio-carbon Age	Δ R	Two Sigma Range and relative area	Reference
Laguas, Guam	Bulk sediment	Wk-7000	4424±73		5145-4860 cal BP (0.705) 5288-5154 cal BP (0.295)	Athens and Ward 1999
Laguas, Guam	Bulk sediment	Wk-7001	4639±68		5113-5062 cal BP (0.047) 5184-5118 cal BP (0.059) 5221-5217 cal BP (0.003) 5240-5240 cal BP (0.000) 5489-5269 cal BP (0.780) 5583-5502 cal BP (0.111)	Athens and Ward 1999
Laguas, Guam	Pavona sp. Coral	Wk-7002	6574±73	-16±87	7353-6830 cal BP (1.000)	Athens and Ward 1999
Laguas, Guam	Wood	Wk-7003	7878±58		8809-8551 cal BP (0.788) 8870-8826 cal BP (0.074) 8977-8880 cal BP (0.138)	Athens and Ward 1999
Laguas, Guam	Wood	Wk-7004	8190±60		9307-9007 cal BP (0.988) 9371-9363 cal BP (0.006) 9395-9385 cal BP (0.006)	Athens and Ward 1999
Tipalao, Guam	Bulk sediment	Beta-60077	3080±70		3095-3078 cal BP (0.018) 3131-3106 cal BP (0.022) 3447-3137 cal BP (0.960)	Athens and Ward 1993
Tipalao, Guam	Bulk sediment	Beta-60078	3700±80		4293-3832 cal BP (1.000)	Athens and Ward 1993
Tipalao, Guam	Bulk sediment	Beta-60079	4950±80		5499-5492 cal BP (0.006) 5902-5583 cal BP (0.994)	Athens and Ward 1993
Tipalao, Guam	Bulk sediment	Beta-60080	6210±70		7269-6938 cal BP (1.000)	Athens and Ward 1993
Tipalao, Guam	Bulk sediment	Beta-62497	2030±60		2146-1868 cal BP (1.000)	Athens and Ward 1993
Upland Pago, Guam	Bulk sediment	Beta-50845	7250±110		7903-7861 cal BP (0.033) 8328-7920 cal BP (0.967)	Ward 1994
Upland Pago, Guam	Bulk sediment	Beta-51410	3070±140		2912-2881 cal BP (0.013) 3574-2918 cal BP (0.987)	Ward 1994
Upland Pago, Guam	Bulk sediment	Beta-51411	6080±80		7164-6747 cal BP (1.000)	Ward 1994
Upland Pago, Guam	Bulk sediment	Beta-51412	9130±140		10691-9897 cal BP (1.000)	Ward 1994

*Table 7. Archaeological data. Ranges marked with a * are suspect due to impingement on the end of the calibration data set*

Site	Context	Dated material	Sample	Radio-carbon Age	Δ R	Two Sigma Range and relative area	Reference
Unai Bapot, Saipan	100-110 cm	Anadara sp. shell	ANU-4767	2680±120	-16±87	2746-2036 cal BP (1.00)	Bonhomme and Craib 1987
Unai Bapot, Saipan	170-190 cm	Anadara sp. shell	ANU-4768	2860±90	-16±87	2906-2314 cal BP (1.00)	Bonhomme and Craib 1987
Unai Bapot, Saipan	40-50 cm	Anadara sp. shell	ANU-4769	620±120	-16±87	*484-1 cal BP (1.00)	Bonhomme and Craib 1987
Unai Bapot, Saipan	310-330 cm; beneath cultural layer	Anadara sp. shell	ANU-4769	3140±120	-16±87	3356-2656 cal BP (1.00)	Bonhomme and Craib 1987
Unai Bapot, Saipan	90-100 cm	Anadara sp. shell	ANU-4770	2520±100	-16±87	2574-1870 cal BP (1.00) 2581-2579 cal BP (0,00) 2591-2589 cal BP (0,00)	Bonhomme and Craib 1987
Unai Bapot, Saipan	135-155 cm	Anadara sp. shell	ANU-4772	2690±120	-16±87	2754-2045 cal BP (1.00)	Bonhomme and Craib 1987
Unai Bapot, Saipan	TU-2, Layer IV-A, localised discard pile; earliest cultural layer	Anadara sp. shell	Beta-202722	3590±40	-16±87	3285-3270 cal BP (0,01) 3762-3290 cal BP (0.99)	Carson 2008
Unai Bapot, Saipan	TU-2, Layer III-A, combustion feature; later cultural layer	Charcoal	Beta-214761	2840±40		3068-2853 cal BP (1.00)	Carson 2008
Unai Bapot, Saipan	TU-2, Layer IV-A, localised discard pile; earliest cultural layer	Anadara sp. shell	Beta-216616	3710±50	-16±87	3905-3398 cal BP (1.00)	Carson 2008
Unai Bapot, Saipan	TU-2, Unit 8, 30-40 cm	Nutshell charcoal	Wk-23750	1386±30		1345-1276 cal BP (1.00)	Clark et al. 2010
Unai Bapot, Saipan	Unit 4, 50-60 cm	Nutshell charcoal	Wk-23751	1581±35		1547-1397 cal BP (1.00)	Clark et al. 2010
Unai Bapot, Saipan	Unit 2, 70-80 cm	Charcoal	Wk-23752	2043±30		2070-1925 cal BP (0.91) 2113-2077 cal BP (0,09)	Clark et al. 2010
Unai Bapot, Saipan	Unit 7, 100-110 cm	Charcoal	Wk-23753	2386±30		2491-2344 cal BP (0.97) 2605-2605 cal BP (0,00) 2656-2643 cal BP (0,02) 2676-2665 cal BP (0,01)	Clark et al. 2010
Unai Bapot, Saipan	Unit 2, 100-110 cm	Charcoal	Wk-23754	2189±30		2309-2127 cal BP (1.00)	Clark et al. 2010

Site	Context	Dated material	Sample	Radio-carbon Age	Δ R	Two Sigma Range and relative area	Reference
Unai Bapot, Saipan	Unit 8, 130-140 cm	Charcoal	Wk-23755	2168±32		2087-2062 cal BP (0,04) 2213-2100 cal BP (0.48) 2309-2218 cal BP (0.48)	Clark et al. 2010
Unai Bapot, Saipan	Unit 5, 130-140 cm	Charcoal	Wk-23756	2175±30		2076-2071 cal BP (0,01) 2309-2112 cal BP (0.99)	Clark et al. 2010
Unai Bapot, Saipan	Unit 7, 150-160 cm	Charcoal	Wk-23757	2907±32		3085-2957 cal BP (0.76) 3157-3086 cal BP (0.24)	Clark et al. 2010
Unai Bapot, Saipan	Unit 5, 180-190 cm	Charcoal	Wk-23760	2866±32		3076-2875 cal BP (1.00)	Clark et al. 2010
Unai Bapot, Saipan	Unit 8, 190-200 cm	Charcoal	Wk-23761	2922±30		3161-2971 cal BP (1.00)	Clark et al. 2010
Unai Bapot, Saipan	Unit 3, 200-210 cm	Nutshell charcoal	Wk-23763	2904±30		3083-2956 cal BP (0.80) 3156-3090 cal BP (0.20)	Clark et al. 2010
Unai Bapot, Saipan	Unit 2, 210-220 cm	Charcoal	Wk-23764	2910±30		3084-2961 cal BP (0.74) 3157-3087 cal BP (0.26)	Clark et al. 2010
Unai Bapot, Saipan	Unit 2, 210-220 cm	Charcoal	Wk-23765	2900±30		3083-2953 cal BP (0.83) 3156-3090 cal BP (0.17)	Clark et al. 2010
Unai Bapot, Saipan	Unit 5, 220-230 cm	Charcoal	Wk-23766	3013±30		3094-3078 cal BP (0,03) 3131-3107 cal BP (0,04) 3260-3137 cal BP (0.78) 3336-3288 cal BP (0.15)	Clark et al. 2010
Unai Bapot, Saipan	Unit 1, 230-240 cm	Charcoal	Wk-23767	3010±30		3095-3077 cal BP (0,04) 3134-3106 cal BP (0,05) 3258-3135 cal BP (0.78) 3334-3289 cal BP (0.12)	Clark et al. 2010
Unai Bapot, Saipan	Unit 4 230-240 cm	Charcoal	Wk-23768	2908±30		3084-2960 cal BP (0.76) 3156-3089 cal BP (0.24)	Clark et al. 2010
Unai Bapot, Saipan	Unit 1, 210-220 cm	Cypraea sp. shell artifact	Wk-23769	3355±30		3325-3117 cal BP (1.00)	Clark et al. 2010
Unai Bapot, Saipan	Unit 1, 210-220 cm	Cypraea tigrisartifact	Wk-23770	3192±30	0±0	3103-2875 cal BP (1.00)	Clark et al. 2010
Unai Bapot, Saipan	Unit 4, 220-230 cm	Conus sp.shell artifact	Wk-23771	3182±30	0±0	3080-2862 cal BP (1.00)	Clark et al. 2010
Unai Bapot, Saipan	Unit2 230-240 cm	Anadara sp. shell	Wk-25210	3484±35	-16±87	3612-3144 cal BP (1.00)	Clark et al. 2010

Site	Context	Dated material	Sample	Radio-carbon Age	Δ R	Two Sigma Range and relative area	Reference
Unai Bapot, Saipan		Charcoal	UCR-649	2980±100		2914-2879 cal BP (0,02) 3380-2916 cal BP (0.98)	Marck 1978
Unai Bapot, Saipan	Lower sample	Charcoal	UCR-650	3000±100		2908-2886 cal BP (0,01) 3400-2921 cal BP (0.99) 3437-3434 cal BP (0,00)	Marck 1978
Achugao, Saipan	Uppermost sample	Charcoal	Beta-28086	2780±50		2996-2770 cal BP (1.00)	Butler 1994, 1995
Achugao, Saipan	Lower-middle sample	Charcoal	Beta-28218	2500±80		2744-2364 cal BP (1.00)	Butler 1994, 1995
Achugao, Saipan	Middle-upper sample	Charcoal	Beta-29087	2950±80		2910-2884 cal BP (0,02) 3275-2919 cal BP (0.90) 3343-3282 cal BP (0,07)	Butler 1994, 1995
Achugao, Saipan	Lowest sample	Charcoal	Beta-36190	3470±120		4005-3451 cal BP (0.97) 4081-4033 cal BP (0,03)	Butler 1994, 1995
Achugao, Saipan	Lowest sample	Charcoal	Beta-36191	3120±50		3447-3213 cal BP (1.00)	Butler 1994, 1995
Chalan Piao, Saipan	Charcoal combined from multiple locations, 36-61 cm	Charcoal	Beta-33390	2930±90		3274-2858 cal BP (0.94) 3342-3283 cal BP (0,06)	Moore et al. 1992
Chalan Piao, Saipan	Charcoal combined from multiple locations, 61-100 cm	Charcoal	Beta-33391	3210±100		3201-3180 cal BP (0,01) 3644-3205 cal BP (0.98) 3686-3664 cal BP (0,01)	Moore et al. 1992
Chalan Piao, Saipan	Unclear context but probably post-dating earliest redware	Oyster shell	Chicago-669	3479±200	0±0	3840-2844 cal BP (1.00)	Spoehr1957:60-67
Unai Chulu, Tinian	Unit 2, Layer III, 40-50 cm; Base of cultural deposit possibly pre-dating this layer	Anadara sp. shell	Beta-62603	3690±100	-16±87	3978-3317 cal BP (1.00)	Craib 1993
Unai Chulu, Tinian	Unit 3, Layer III, 45-55 cm	Anadara sp. shell	Beta-62604	3190±50	-16±87	3267-2761 cal BP (1.00)	Craib 1993
Unai Chulu, Tinian	Unit 3, Layer III, 55-65 cm	Anadara sp. shell	Beta-62605	3290±50	-16±87	3379-2869 cal BP (1.00)	Craib 1993

Site	Context	Dated material	Sample	Radio-carbon Age	Δ R	Two Sigma Range and relative area	Reference
Unai Chulu, Tinian	Unit 3, Layer III, 70-80 cm; at base of cultural deposit, possibly pre-dating this layer	Anadara sp. shell	Beta-62606	3400±70	-16±87	3552-2980 cal BP (1.00)	Craib 1993
Unai Chulu, Tinian	Unit 3, Layer III, 55-67 cm	Bulk sediment	Beta-62607	2530±60		2393-2380 cal BP (0,01) 2411-2405 cal BP (0,01) 2755-2426 cal BP (0.98)	Craib 1993
Unai Chulu, Tinian	Unit 3, Layer IV, 90-100 cm; Pre-dates cultural layer; Shell taxon may not be reliable for dating, subject to possible marine upwelling	Turbo sp. shell	Beta-62608	4060±50	0±0	4246-3926 cal BP (1.00)	Craib 1993
Unai Chulu, Tinian	Stratum VII, 210-220 cm	Charcoal	Beta-81946	3120±50		3447-3213 cal BP (1.00)	Haun et al. 1999
Unai Chulu, Tinian	Stratum VII, 220 cm	Charcoal	Beta-81947	3070±100		3478-2969 cal BP (1.00)	Haun et al. 1999
Unai Chulu, Tinian	Stratum VII, Feature 494, 227-249 cm	Charcoal	Beta-81948	3100±60		3447-3165 cal BP (1.00)	Haun et al. 1999
Unai Chulu, Tinian	Stratum VII, 210-220 cm	Charcoal	Beta-81949	2940±70		2910-2884 cal BP (0,02) 3257-2919 cal BP (0.94) 3332-3290 cal BP (0,04)	Haun et al. 1999
Unai Chulu, Tinian	Stratum VII, 230-244 cm	Charcoal	Beta-81950	3020±60		3012-3008 cal BP (0,00) 3050-3032 cal BP (0,01) 3368-3056 cal BP (0.98)	Haun et al. 1999
Unai Chulu, Tinian	Stratum VII, 244 cm	Charcoal	Beta-81951	3070±60		3094-3078 cal BP (0,02) 3130-3107 cal BP (0,02) 3401-3137 cal BP (0.96) 3439-3433 cal BP (0,00)	Haun et al. 1999
Unai Chulu, Tinian	Stratum VII, 244-250 cm	Charcoal	Beta-81952	3110±60		3449-3172 cal BP (1.00)	Haun et al. 1999
Unai Chulu, Tinian	Stratum VII, 250-260 cm	Charcoal	Beta-81953	2990±50		3269-3003 cal BP (0.90) 3338-3287 cal BP (0.10)	Haun et al. 1999
Unai Chulu, Tinian	Stratum VII, 250-260 cm	Charcoal	Beta-81954	3050±60		3382-3075 cal BP (1.00)	Haun et al. 1999

Site	Context	Dated material	Sample	Radio-carbon Age	Δ R	Two Sigma Range and relative area	Reference
Unai Chulu, Tinian	Stratum VII, 258-273 cm	Charcoal	Beta-81955	3040±60		3379-3068 cal BP (1.00)	Haun et al. 1999
Unai Chulu, Tinian	Stratum VII, 227-249 cm	Charcoal	Beta-83213	3080±40		3199-3181 cal BP (0,03) 3379-3206 cal BP (0.97)	Haun et al. 1999
Unai Chulu, Tinian	Stratum VII, 220-230 cm	Charcoal	Beta-83214	3000±40		3271-3063 cal BP (0.88) 3340-3286 cal BP (0.12)	Haun et al. 1999
Unai Chulu, Tinian	Stratum VII, Feature 520. 268-283 cm	Charcoal	Beta-83216	2920±40		3180-2951 cal BP (1.00) 3205-3201 cal BP (0,00)	Haun et al. 1999
Unai Chulu, Tinian	Stratum VII, Feature 488, 220-230 cm	Bulk sediment	GX-20795	2215±135		2516-1885 cal BP (0.95) 2538-2526 cal BP (0,00) 2616-2588 cal BP (0,01) 2698-2633 cal BP (0,03)	Haun et al. 1999
Unai Chulu, Tinian	Stratum VII, Feature 500. 241-262 cm	Bulk sediment	GX-20796	2565±70		2395-2379 cal BP (0,01) 2414-2399 cal BP (0,01) 2787-2422 cal BP (0.98)	Haun et al. 1999
Unai Chulu, Tinian	Stratum VII, Feature 520. 268-283 cm	Bulk sediment	GX-20797	2035±135		2335-1708 cal BP (1.00)	Haun et al. 1999
House of Taga, Tinian	Latte-associated cultural deposit; rubbish pit feature	Charcoal (narrow twigs)	Beta-313865	760±30		729-667 cal BP (1.00)	Carson 2014
House of Taga, Tinian	Lowest cultural deposit; Hearth feature A	Charcoal (narrow twigs)	Beta-313866	3070±30		3190-3184 cal BP (0,01) 3363-3209 cal BP (0.99)	Carson 2014
House of Taga, Tinian	Lowest cultural deposit; Rubbish pit feature D	Charcoal (narrow twigs)	Beta-313867	3070±30		3190-3184 cal BP (0,01) 3363-3209 cal BP (0.99)	Carson 2014
House of Taga, Tinian	Lowest cultural deposit; Small hearth feature I	Anadara sp. shell	Beta-313868	3480±30	-16±87	3604-3144 cal BP 1.0	Carson 2014
House of Taga, Tinian	Lowest cultural deposit; Rubbish pit feature E	Anadara sp. shell	Beta-313869	3440±30	-16±87	3557-3090 cal BP (1.00)	Carson 2014
House of Taga, Tinian	Natural beach deposit, Pre-dated cultural activity	Acropora sp. branch coral	Beta-313870	4570±30	-16±87	5036-4518 cal BP (1.00)	Carson 2014

Site	Context	Dated material	Sample	Radio-carbon Age	Δ R	Two Sigma Range and relative area	Reference
House of Taga, Tinian	Lowest cultural deposit; Hearth feature C	Anadara sp. shell	Beta-316282	3400±30	-16±87	3508-3028 cal BP (1.00)	Carson 2014
House of Taga, Tinian	Lowest cultural deposit; Hearth feature A	Anadara sp. shell	Beta-316283	3390±30	-16±87	3488-3008 cal BP (1.00)	Carson 2014
House of Taga, Tinian	Lowest cultural deposit; Hearth feature B	Anadara sp. shell	Beta-316284	3500±30	-16±87	3625-3167 cal BP (1.00)	Carson 2014
House of Taga, Tinian	Upper cultural deposit, thick-coarse redware; small hearth feature	Charcoal (narrow twigs)	Beta-316285	2940±30		3180-2991 cal BP (0.99) 3206-3199 cal BP (0,01)	Carson 2014
Ritidian, Guam	98-105 cm; upper cultural layer	Cellana sp. (limpet) shell	Beta-239576	5810±40	2810±40	2913-2680 cal BP (1.00)	Carson 2010. 2012a
Ritidian, Guam	98-105 cm; upper cultural layer	Charcoal	Beta-239577	2810±40		3006-2792 cal BP (0.99) 3023-3014 cal BP (0,01) 3030-3029 cal BP (0,00)	Carson 2010, 2012a
Ritidian, Guam	105-115 cm; upper cultural layer	Anadara sp. shell	Beta-239578	3140±40	13±58	3099-2747 cal BP (1.00)	Carson 2010, 2012a
Ritidian, Guam	250-260 cm; deepest cultural layer	Anadara sp. shell	Beta-253681	3430±40	-16±87	3553-3063 cal BP (1.00)	Carson 2010, 2012a
Ritidian, Guam	255-260 cm; deepest cultural layer	Halimeda sp. bioclastic sand	Beta-253682	3480±40	-16±87	3615-3135 cal BP (1.00)	Carson 2010, 2012a
Ritidian, Guam	260-265 cm, pre-dates cultural layer	Heliopora sp. coral limestone	Beta-253683	4100±50	-16±87	4431-3883 cal BP (1.00)	Carson 2010, 2012a
Ritidian, Guam	262263 cm; pre-dates cultural layer	Acropora sp. branch coral	Beta-303807	3750±30	-16±87	3943-3463 cal BP (1.00)	Carson 2010, 2012a
Ritidian, Guam	110-120 cm; natural surge layer	Acropora sp. branch coral	Beta-303808	3260±30	-16±87	3339-2861 cal BP (1.00)	Carson 2010, 2012a
Tarague, Guam	Layer VIII	Marine shells (limpets)	Beta-4897	3435±70	0±0	3475-3115 cal BP (1.00)	Kurashina et al. 1981
Mangilao Golf Course, Guam	Site 25, EU-246 Layer IIIg2 level 12	Charcoal	Beta-46502	2950±60		2934-2929 cal BP (0,00) 3256-2943 cal BP (0.96) 3331-3291 cal BP (0,04)	Dilli et al. 1998

Site	Context	Dated material	Sample	Radio-carbon Age	Δ R	Two Sigma Range and relative area	Reference
Mangilao Golf Course, Guam	Site 25, EU-243, Layer IIIg2, level 13	Charcoal	Beta-53472	3150±60		3187-3185 cal BP (0,00) 3483-3209 cal BP (0.99) 3491-3489 cal BP (0,00) 3549-3534 cal BP (0,01)	Dilli et al. 1998
Mangilao Golf Course, Guam	Site 25, EU-243 Layer IIIg2, level 12	Charcoal	Beta-67869	2980±70		3350-2962 cal BP (1.00)	Dilli et al. 1998
Mangilao Golf Course, Guam	Site 25, EU-248 Layer IIIg2, level 11	Charcoal	Beta-67870	2950±70		2904-2892 cal BP (0,01) 3269-2923 cal BP (0.94) 3338-3287 cal BP (0,06)	Dilli et al. 1998
Mangilao Golf Course, Guam	Site 25, EU-248, Layer IIIg2, level 12	Charcoal	Beta-67871	3200±90		3188-3185 cal BP (0,00) 3636-3209 cal BP (1.00)	Dilli et al. 1998
Mangilao Golf Course, Guam	Site 25, EU-245, Layer IIIg2, level 12	Charcoal	Beta-67874	2780±60		3008-2759 cal BP (0.98) 3033-3012 cal BP (0,02) 3055-3054 cal BP (0,00)	Dilli et al. 1998
Mangilao Golf Course, Guam	Site 25, EU-243 Layer IIIg2, level 12	Charcoal	Beta-67875	2970±60		3268-2961 cal BP (0.93) 3337-3287 cal BP (0,07)	Dilli et al. 1998
Mangilao Golf Course, Guam	Site 25, EU-241 Layer IIIg2, level 10	Charcoal	Beta-67876	3030±90		3405-2962 cal BP (0.99) 3442-3428 cal BP (0,01)	Dilli et al. 1998
Nomna, Guam	Unit 3-1-1, 18-24 inches	Charcoal	GaK-1362	770±80		602-558 cal BP (0,07) 832-629 cal BP (0.85) 906-848 cal BP (0,08)	Reinman 1977:32-42
Nomna, Guam	Unit 4-1-3, 24-30 inches	Charcoal	GaK-1363	2050±110		1755-1741 cal BP (0,01) 1794-1783 cal BP (0,01) 2323-1808 cal BP (0.99)	Reinman 1977:32-42
Nomna, Guam	Unit 6-1-1, 6-12 inches; possibly 12-18 inches	Charcoal	GaK-1364	3270±170		3926-3064 cal BP (1.00) 3960-3949 cal BP (0,00)	Reinman 1977:32-42
Nomna, Guam	Unit 6-1-1, 18-24 inches	Charcoal	GaK-1365	280±70		25-*1 cal BP (0,03) 221-140 cal BP (0.14) 503-260 cal BP (0.83)	Reinman 1977:32-42
Nomna, Guam	Unit 6-2-1, 6-12 inches	Charcoal	GaK-1366	590±90		697-481 cal BP (1.00)	Reinman 1977:32-42

Site	Context	Dated material	Sample	Radio-carbon Age	Δ R	Two Sigma Range and relative area	Reference
Nomna, Guam	Unit 6-2-1, 24-30 inches	Charcoal	GaK-1367	980±90		1063-699 cal BP (1.00)	Reinman 1977:32-42
Nomna, Guam	Unit 6-1-1, 6-12 inches	Charcoal	GaK-1696	1110±80		807-804 cal BP (0,00) 851-831 cal BP (0,01) 1189-906 cal BP (0.94) 1259-1202 cal BP (0,05)	Reinman 1977:32-42
Nomna, Guam	Unit 6-1-1, 12-18 inches; possibly 6-12 inches	Charcoal	GaK-1697	1070±70		815-799 cal BP (0,02) 868-823 cal BP (0,05) 1176-900 cal BP (0.93)	Reinman 1977:32-42
Nomna, Guam	Unit 6-1-1, 18-24 inches	Charcoal	GaK-1698	1460±80		1197-1193 cal BP (0,00) 1540-1261 cal BP (1.00)	Reinman 1977:32-42
Nomna, Guam	Unit 4-4-18, 6-12 inches	Charcoal	UCLA-1232G	320±80		*14-1 cal BP (0,01) 189-146 cal BP (0,05) 213-192 cal BP (0,01) 518-268 cal BP (0.92)	Reinman 1977:32-42
Nomna, Guam	Unit 4-4-18, 6-12 inches	Pottery sherd	UCLA-1232H	275±80		*33-1 cal BP (0,05) 100-74 cal BP (0,02) 114-105 cal BP (0,01) 225-136 cal BP (0.17) 505-254 cal BP (0.76)	Reinman 1977:32-42
Nomna, Guam	Unit 4-4-18, 18-24 inches	Charcoal	UCLA-1232I	805±80		580-571 cal BP (0,01) 917-651 cal BP (0.99)	Reinman 1977:32-42
Nomna, Guam	Unit 4-4-18, 18-24 inches	Pottery sherd	UCLA-1232J	670±100		786-511 cal BP (1.00)	Reinman 1977:32-42
Tumon, Guam	Matapang Area B, Unit 127, hearth feature	Charcoal	Beta-14704	3170±70		3562-3222 cal BP (1.00)	Bath 1986:25-100
Tumon, Guam	Matapang Area A, Backhoe Trench 1, hearth feature	Charcoal	Beta-14705	3880±90		4040-3993 cal BP (0,02) 4528-4074 cal BP (0.98)	Bath 1986:25-100
Tumon, Guam	Feature 2	Bulk sediment	Beta-238482	1680±40		1453-1445 cal BP (0,01) 1704-1522 cal BP (0.99)	DeFant 2008

Site	Context	Dated material	Sample	Radio-carbon Age	Δ R	Two Sigma Range and relative area	Reference
Tumon, Guam	Burial 173	Conus sp. shell beads	Beta-238483	2940±40	0±0	2627-2615 cal BP (0,01) 2821-2641 cal BP (0.99)	DeFant 2008
Tumon, Guam	Burial 156	Conus sp. shell beads	Beta-238484	2790±40	0±0	2681-2380 cal BP (1.00)	DeFant 2008
Tumon, Guam	Burial 273	Conus sp. shell beads	Beta-238485	2860±40	0±0	2728-2485 cal BP (1.00)	DeFant 2008
Tumon, Guam	Burial 286	Conus sp. shell beads	Beta-238486	2970±40	0±0	2838-2681 cal BP (1.00)	DeFant 2008
Tumon, Guam	Ypao Beach Park, Unit 74.204, post mold, 70 cm	Charcoal	CAMS-7868	2700±70		2963-2722 cal BP (1.00)	Olmo and Goodman 1994:38
Hagatna, Guam	Plaza de Espana, base of cultural deposit	Charcoal	Not reported	2580±100		2853-2361 cal BP (1.00)	Cordy and Allen 1986:34
Hagatna, Guam	Plaza de Espana, pre-dates cultural layer	Marine bivalve shell	Not reported	2970±100		2990-2450 cal BP (1.00)	Cordy and Allen 1986:34

7.6. Pottery, non-ceramic artefacts and fauna

7.6.1. Methodology

As is common for archaeological sites in the West Pacific islands, ceramics are the most abundant category of cultural material at Bapot-1, Block A. Ceramics from Block A are described in terms of diagnostic features that have been used by archaeologists to register sequence change in the Marianas (Spoehr 1957; Reinman 1977; Thompson 1979; Leidemann 1980; Ray 1981; Moore 1983, 2002; Butler 1995).

In Chapter 1, it was stated that a main objective of this thesis was the study of the earliest cultural material in the Marianas, and that the focus would be on the ceramics dated to the Early Pre-Latte period. This chapter considers the material culture and faunal sequence from Bapot, examining first, the pottery from all layers in order to construct a ceramic sequence which can be linked with radiocarbon dates, and compared with other early assemblages from the Marianas. Finally, the Early Pre-Latte assemblage from Bapot will be compared with ceramic assemblages of approximately the same time period from Taiwan, Philippines, Palau and from the Bismarck Archipelago. Furthermore, the Block A excavation produced a large amount of shell and lithic artefacts and faunal remains that will be presented in this chapter and in Appendix 2 and 3. No detailed study of shell and lithic material is included in this thesis, but summaries of finds are given. The faunal remains, especially food shells, are the subject of a PhD-study by Pat O'Day (2015) and are summarised here as well.

7.6.2. Ceramic data collection

The ceramic assemblage from the Block A excavation consisted of 19 307 sherds with a total weight of 68 kg from units 1-9. In the first stage of the analysis, the entire pottery assemblage from all units and all layers was examined and weighed, and all sherds with diagnostic traits (rims, decoration, surface treated) were extracted for further analysis. The diagnostic assemblage totalled 770 sherds and contains 37 decorated sherds (12.6 kg). The diagnostic sherds were categorised according to rim type, ware type, vessel type/diameter and decoration. Secondly, to narrow the analysis, all body sherds > 1 cm in greatest length from the north face units 1-3 were counted, weighed and examined. This assemblage comprised 8304 sherds weighing 22.8 kg. Sampled sherds from the north face unit were recorded as follows: temper type, sherd size and colour, wall thickness and surface treatment (decoration, slip) In addition, a subset of these sherds was used to study ceramic manufacturing techniques using a new method not used previously to examine archaeological ceramics in the Indo-Pacific.

Figure 39. Total number of sherds by 10 cm level.

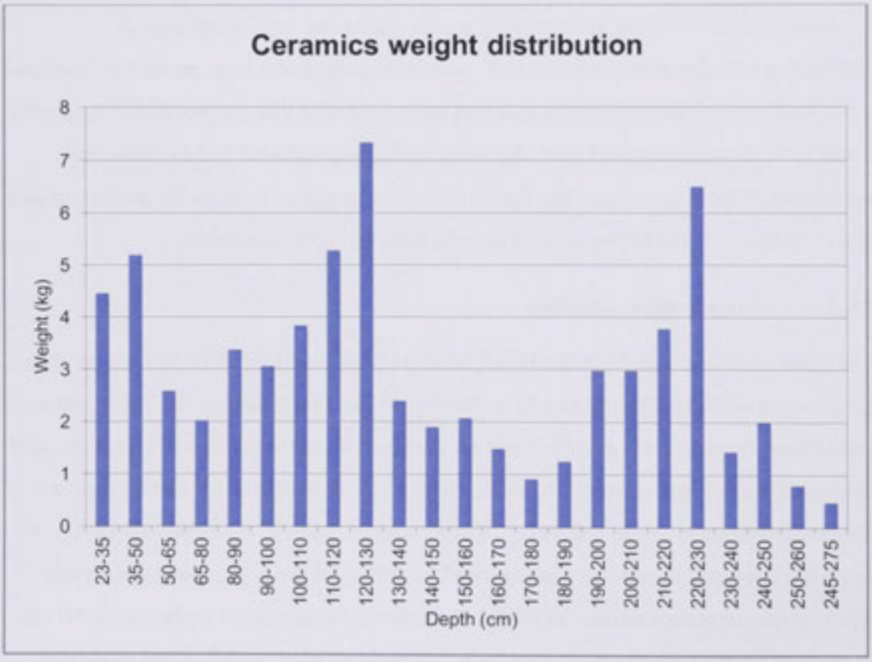


Figure 40. Ceramic weight distribution. Combined sherd mass from each depth unit.

7.6.3. Chaîne opératoire

The notion of *chaîne opératoire* has been widely used in technological analysis, and especially in the study of pottery technology since the 1970s. The concept of *chaîne opératoire* encompasses a robust framework for organising all technological choices regarding material and techniques involved in the pottery production process. The concept involves the use of a 'recipe' related to specific social dynamics that regulate the production process from the choice of raw material to the technique used by the potter, to the final product. These choices are the consequence of the technological knowledge acquired by an individual as a result of her or his social behaviour and interaction. Anthropological and sociological studies have shown that technology is closely linked to social and symbolic phenomena that are characteristics of the society that performs the technical acts. The concept of *chaîne opératoire* has great potential to explain the social phenomena behind the technology of artefacts (Santacreu 2014:53-54).

Instead of understanding technology from an evolutionary or functionalist perspective, the notion of the *chaîne opératoire* argues that technology is related to a certain *savoir faire* (know-how) and incorporates the social dimension of the technique. Manufacturing pottery involves characteristic sequences of technical choices. The potters select certain clays, adds certain tempers, and builds certain type of vessels, with a particular technique, and finally fires the completed vessel at a certain heat. All these choices leading to the creation of particular kinds of vessels, represent a means by which humans, either consciously or unconsciously, attempt to address purposes that goes beyond the material itself (Santacreu 2014:56). This thesis will analyse some of the stages that compose the pottery *chaîne opératoire* in order to better comprehend the physical process involved in the manufacturing of ceramics. By identifying the technical processes, the aim is to understand a portion of the material culture of the first settlers of the Mariana Islands and then to investigate cultural relationships in the Indo-Pacific region by comparing the Bapot *chaîne opératoire* with the *chaîne opératoire of* other Neolithic pottery-producing people.

The phases of the pottery *chaîne opératoire* discussed are:

1. Clay selection
2. Paste preparation
3. Modelling/Manufacturing technique
4. Surface treatment
5. Firing

Clay

Ceramics consist of two main ingredients: clay and water (or some other liquid). Clay is defined as a fine-grained earth material that in combination with water, develops a certain plasticity (Shepard 1956:6). Clay is also a geological term which is used to define certain components of mineral particles, and also a sediment size class. When sediment particles are less than 2 micrometres (0.002 mm) in diameter they are termed *clay-sized*. The major chemical components of clay minerals are silica, aluminium and water (Shepard 1956:6ff; Papmehl-Dufay 2006:138), and they are produced by mechanical or chemical weathering of rock (Rice 1987:34). When found in their place of origin they are known as residual or primary clays, while clays that have been transported by water and wind and deposited in layers of sediment are known as sedimentary or secondary clays (Rice 1987:36).

Because primary clays are found in the places they were formed, the particles tend not to be well-sorted, while the transportation processes (wind and water action) affecting secondary clays mean the particles will usually have been ground further. This means secondary clays are often more fine-grained with higher organic content than residual or primary clays (Papmehl-Dufay 2006:138). In this research, 23 Bapot sherds were cut and polished, and studied microscopically to evaluate the properties of the clay. Grains and grain size in the clay were analysed to determine the potter's choice of clay and whether or not he/she needed to add temper. (Figure 43, Figure 44) This type of study gives important information about the manufacturing tradition used to make prehistoric pottery.

All ceramics found in early sites in the Mariana Islands appear to be produced from local clays (Graves *et al.* 1990). There are several areas with suitable clay sources for pottery production, especially along streams and rivers where iron-rich sedimentary clay deposits are easily available (Carson 2014:55).

For Unai Bapot there are good clay sources consisting of Lao Lao-Akina soil, some kilometres inland and behind the site. Lao Lao-Akina soil is ferruginous with 60 to 80 percent clay (in the argillic horizon). It is reddish brown (5YR 4/4), very sticky and very plastic (National Cooperative Soil Survey U.S.A. 2005). A total of 110 sherds from all levels of the Bapot site were analysed by Christian Reepmeyer at ANU using a pXRF machine. The elemental composition of the sherds was carried out in order to identify compositional variability in sherds and whether any of the sampled sherds contained elements that might have been exotic to Saipan. Although the analysis was calibrated with basalt data rather than a calibration specifically designed for ceramics, the results provides a good idea of the main elements in the Unai Bapot ceramics.

All sherds have a high iron signature (see Figure 41), which fits well with Carson's (2014:55) observation of easily available iron-rich sedimentary clay deposits. Some sherds have a very high strontium signature, which most likely derives from a temper of crushed sea shell. Marine shells are known to pick up Sr from sea water. Graves *et al.*'s (1990) SEM and EDS study of ceramic clay pastes from the Mariana Islands showed that four different clay sources were used in the assemblage of 34 sherds they analysed from Saipan, Guam, and Aguigan, two sherds derived from Saipan and two from Guam. The study showed that during the Pre-Latte Period, ceramics seem to have been produced from a greater variety of clays than during the Latte Period. At Bapot, Graves *et al.* (1990) note that there is some evidence of both intra-island and inter-island exchange of pottery while at Chalan Piao, all ceramics derive from the same source, and most likely were made at the site with a local clay (Graves *et al.* 1990:226). The same soil type, Lao Lao-Akina soil, which is found in close vicinity to Unai Bapot, is also found very close to the site of Chalan Piao and to Achuago and San Roque, the other two Early Pre-Latte sites on Saipan (see Figure 42). Ancient potters evidently did not need to go very far to find suitable clay for pottery-manufacturing at these sites. It may be a coincidence that all Early Pre-Latte settlement on an island as small as Sapian are just a few kilometeres from good clay sources, but it could also have been a delibaretely choice. Being close to a useful raw material might have been a consideration when selecting an area to settle (Santacreu 2014).

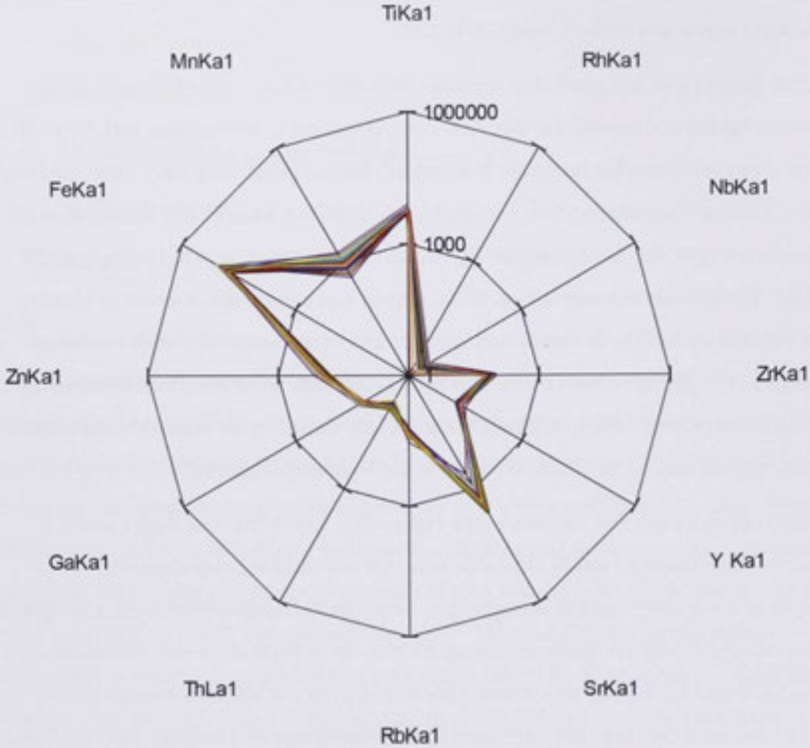


Figure 41. pXRF results of trace elements (ppm) in Bapot sherds. Note the high Fe and variation in Sr caused by use of a marine shell temper. Each coloured line shows the levels in ppm (from 0 ppm to the outer circle, 1 000 000 ppm) for 12 analysed trace elements in one sherd. Chart displays all 110 sherds analysed.

Finds of clay and red ochre together with tools interpreted as anvil stones in the very earliest layers of the Bapot-1 excavation show that local pottery production started immediately after people arrived in the islands, indicating that suitable clay was quickly found.

Figure 42. Soil map of Saipan (after General Soil Map, United States Department of Agriculture, Soil Conservation Service, n.d.). Purple dots indicate good clay sources.

Paste preparation

When the potter adds water to the clay, the clay develops plasticity that allows it to be shaped into various forms and to retain that shape. When the clay dries, it hardens and loses its plasticity and normally shrinks by 5-15%. The drying process is undertaken at a normal temperature and at the end of drying the clay mineral particles come into physical contact with each other and the clay reaches a 'leather-hard stage'. This is when the finishing touches such as decoration and surface treatments are applied (Nordström 1972:37; Papmehl-Dufay 2006:139).

The dried clay object is very fragile and still contains water at this stage. To remove the water and to turn the object into its permanent form, the potter has to heat it to a sufficient temperature to cause the free and bound water to evaporate, with free water usually driven off between 100-300 degrees Celsius. To remove the chemically bound water, the object has to be heated to approximately 400-500 degrees Celsius. The firing process results in the majority of the clay minerals being destroyed and new crystals of ceramic material being formed so that the clay cannot absorb water anymore (Lindahl *et al*. 2006; Papmehl-Dufay 2006:139).

The firing of a ceramic product is the most critical stage in pottery manufacture. The heat causes the water to expand and escape as steam, and thus the wet clay fabric requires porosity and voids for the steam to escape without resistance. If the ceramic object lacks this porosity, the vessel will spall or explode. This problem is often solved by adding a non-plastic inclusion (temper) to the clay before the vessel is shaped (Lindahl 2002).

Temper addition

The function of adding temper sand as aplastic grit to plastic clay is to make the clay more workable when manufacturing vessels. The temper also serves the function of binding the clay during vessel-drying before firing. The temper sand reduces rapid shrinkage and/or expansion during the firing process and provides escape routes for the free and bound water present in the clay body. In archaeology, there is a distinction between natural and added temper. A 'natural' temper is when the clay itself contains aplastic constituents, often referred to as *inclusions,* and there is no need for manipulation to introduce it through the clay, while 'added' temper is when the potter deliberately adds temper to the clay to obtain a workable clay. A study of temper sands by petrographic methods can provide physical evidence for transport of ceramics or raw material between different islands. Petrographic evidence that a material is foreign is more secure than stylistic analysis, since styles can be copied (Dickinson 2006:3). The identification of inclusions as being naturally occurring or intentionally added is often difficult, but can often be solved by a thin sections study. In thin section, clear distinctions in grain size distribution can be detected, which would not be expected in naturally tempered material (See Figures 43 and 44). Or, if it is crushed rock that has been added, it can be detected by the homogeneous mineralogical composition and angular shape of temper grains (Papmehl-Dufay 2006:140). The choice of temper has a great influence on the final product, but clay might also be mixed for other purposes. Petrographic studies can distinguish variation between ceramic assemblages resulting from material source differences and those reflecting different pottery traditions (Lindahl and Matenga 1995:27; Lindahl and Pikirayi 2010; Winter *et al.* 2012).

At Bapot 1, and on all other early sites in the Mariana Islands, the most common temper used in the earliest pottery manufacturing is calcareous sand (Dickinson *et al*. 2001). From a technological point of view, calcareous sand is not a good choice of temper material and should generally be avoided, since calcium carbonate has negative effects on ceramic production during firing. At temperatures above 650 C, the calcium carbonate starts to decompose through the loss of carbon dioxide. After cooling, the remaining calcium oxide rehydrates and forms calcium hydroxide which causes a volume expansion which can result in the vessel's disintegration (Shepard 1956:22, 30; Rice 1987:478; Moore 2002:15; Papmehl-Dufay 2006:141; Winter *et al.* 2012). This process, commonly known as lime blowing, is well understood by potters and most often avoided by choosing a less carbonaceous temper material if one is available. It has been demonstrated that, due to thermal expansion patterns that are similar in most common clays, calcium carbonate is beneficial for use in pots intended for cooking (Rye 1976:116-117). One way of avoiding accidents while manufacturing pots with calcareous clay or added calcareous temper is to use a material with a small grain size. Furthermore, addition of salt and/or organic material has been shown to slow down or hinder the process of decomposition (Rye 1981:127f; Papmehl-Dufay 2006:141; Winter *et al.* 2012).

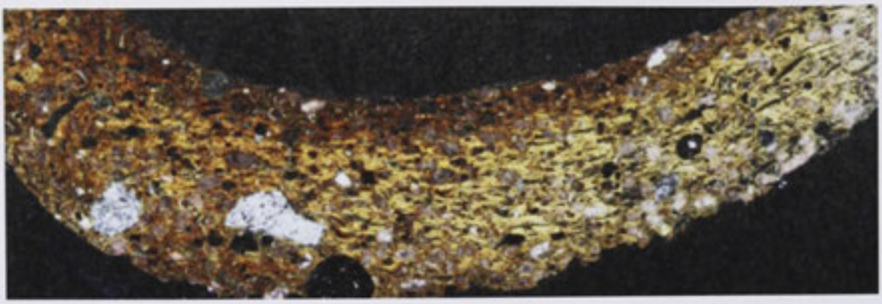


Figure 43. Thin section of BAT 1 showing calcareous sand in the sherd.

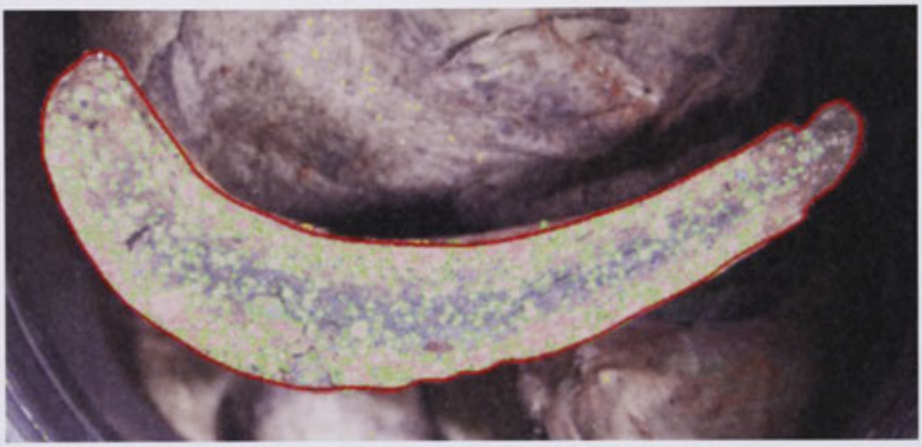


Figure 44. Picture of BAT 1 with all inclusions in the clay marked in green.

As mentioned above, calcareous sand is the most common temper in early ceramics from the Mariana Islands, even although other preferable materials were available (see **Error! Reference source not found.**), and these were used later in prehistory from approximately 2000 BP when volcanic sand becomes increasingly dominant. Carson (2014) has offered an explanation for this pattern: "The preference for fine-grain beach-sand temper may have been the only practical choice for making the thin vessel walls [...] The alternatives of quartz and volcanic sands mostly would include 1-2 mm grains, compared to the general 1-2 mm thickness of the pots" (Carson 2014:55).

Figure 45. Volcanic placer sand on the beach strand east of Bapot Block A. Photo: G. Clark.

Although there are very thin-walled vessels from the earliest phase of the Mariana prehistory (1-4 mm), my study does not support Carson's statement that the early pots generally have 1-2 mm thick walls. Less than 10% of the sherds I studied derive from vessels with 1-2 mm thin walls and the majority of early sherds are 4-6 mm thick; still relatively thin, but thick enough for a temper of quartz and volcanic sand.

7.6.4. Mariana Islands tempers

Dickinson proposed that the Mariana ceramic tempers could be subdivided into seven generic groups (for specific petrographic information see report WRD-285 in Appendix 1): CST – exclusively calcareous sands; VST – generally quartz-free volcanic sands; VQT – volcanic sands in which quartz is prominent; QT – volcanic sands in which quartz is the dominant grain type; CQT – hybrid sands composed exclusively or predominately of quartz and calcareous grains and ST – grog aggregates (very rare). All terrigenous grains found in Mariana tempers derive from andesitic and dacitic bedrock exposed on the inhabited islands in the south rather than from the northern volcanic islands (Dickinson 2006:40).

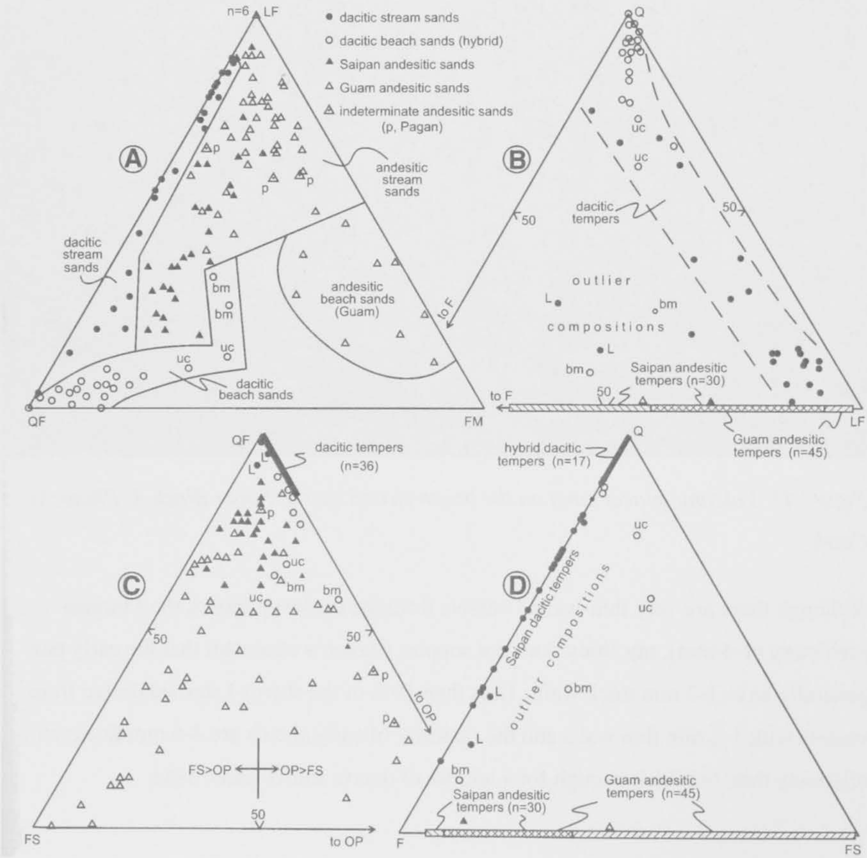


Figure 46. Compositions (grain frequency percentages) of beach and stream sand tempers in sherds from the Mariana Islands (After Dickinson 2006:43).

In assemblages from the oldest Marianas sites, calcareous sand temper (CST), including some with a quartz/volcanic admixture, is always dominant: At Achugao, >80% of early sherds had CST (Butler 1995), at Unai Chulu 60% of early rims and decorated sherds had CST (Haun *et al.* 1999), and at Unai Bapot (2008), >80% of the early pottery had CST. After 2000 BP, volcanic sand became a significant temper source at Unai Bapot (Winter *et al.* 2012).

A selection of 640 sherds, 10 from each unit of the north face of Block A (unit 1-3 and 10 sherds from feature K) and 30 sherds from every layer were sectioned and examined under low-powered magnification to distinguish different temper types (see Figure 47). Furthermore, thin sections of twenty-two sherds were studied petrographically by William Dickinson (see Appendix 1: Petrographic report WRD-285) to obtain a more precise picture of the temper sands that were used over time at Unai Bapot.

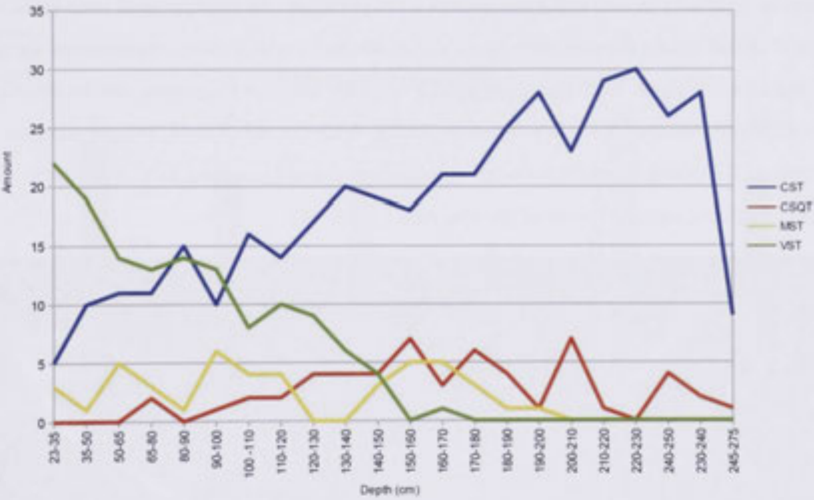


Figure 47. Different temper sand in sherds from 2008 excavation at Unai Bapot. (n=30) sherds from every layer. See below for descriptions of temper types.

7.6.5. Pottery manufacturing techniques

The shaping and squeezing of clay by a potter when making a vessel creates numerous tiny air pockets which become pores in the fabric of the fired ceramic. The different techniques for forming a vessel leave distinct signatures in the ware. By examining the orientation of the pores, it is possible to determine whether a pot was formed by coiling, pulling or a 'paddle and anvil' technique. The forming mode may sometimes be distinguished in the breakage pattern of a sherd, and in some rare cases, it is possible to determine the formation technique through observing a fresh breakage (e.g. Rye 1976; Lindahl and Pikirayi 2010; Winter *et al.* 2012). The study of forming techniques through binocular and petrographic microscope, or X-radiography has had a low rate of use compared to provenance studies and other aspects of pottery technology, since microscopic studies are assumed to be less affordable than macroscopic studies (Santacreu 2014). The best way to determine the orientation of the pores is to study a polished surface of a sherd thin section. This gives a clear image of the pore structure so that joints of the coil and/or diagonal pores from paddle and anvil technique can be identified. However, even then, it is often difficult to accurately identify the forming technique. To enhance the visibility of the thin section, a new method developed at the Laboratory for Ceramic Research in Lund University (Sweden), was used in this research. Surfaces of sectioned rim sherds were polished and impregnated with araldite plastic mixed with a fluorescence agent and examined under a stereo microscope with the aid of a UV light. With this technique, even very small or thin pores can be observed (Lindahl and Pikirayi 2010; Winter *et al.* 2012). With the aid of the UV-light method, a sample of 23 sherds from Bapot were thin-sectioned and examined, with a focus on sherds from the earliest layers of the site (see Figure 48).

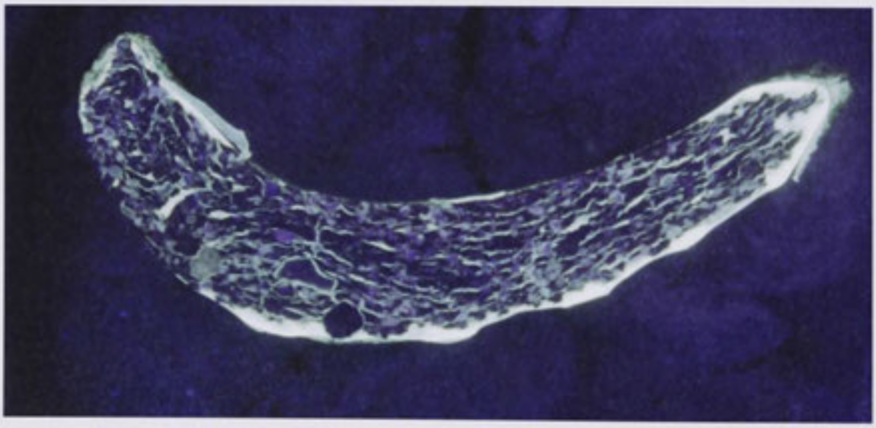


Figure 48. Sherd impregnated with fluorescent agent photographed in UV light.

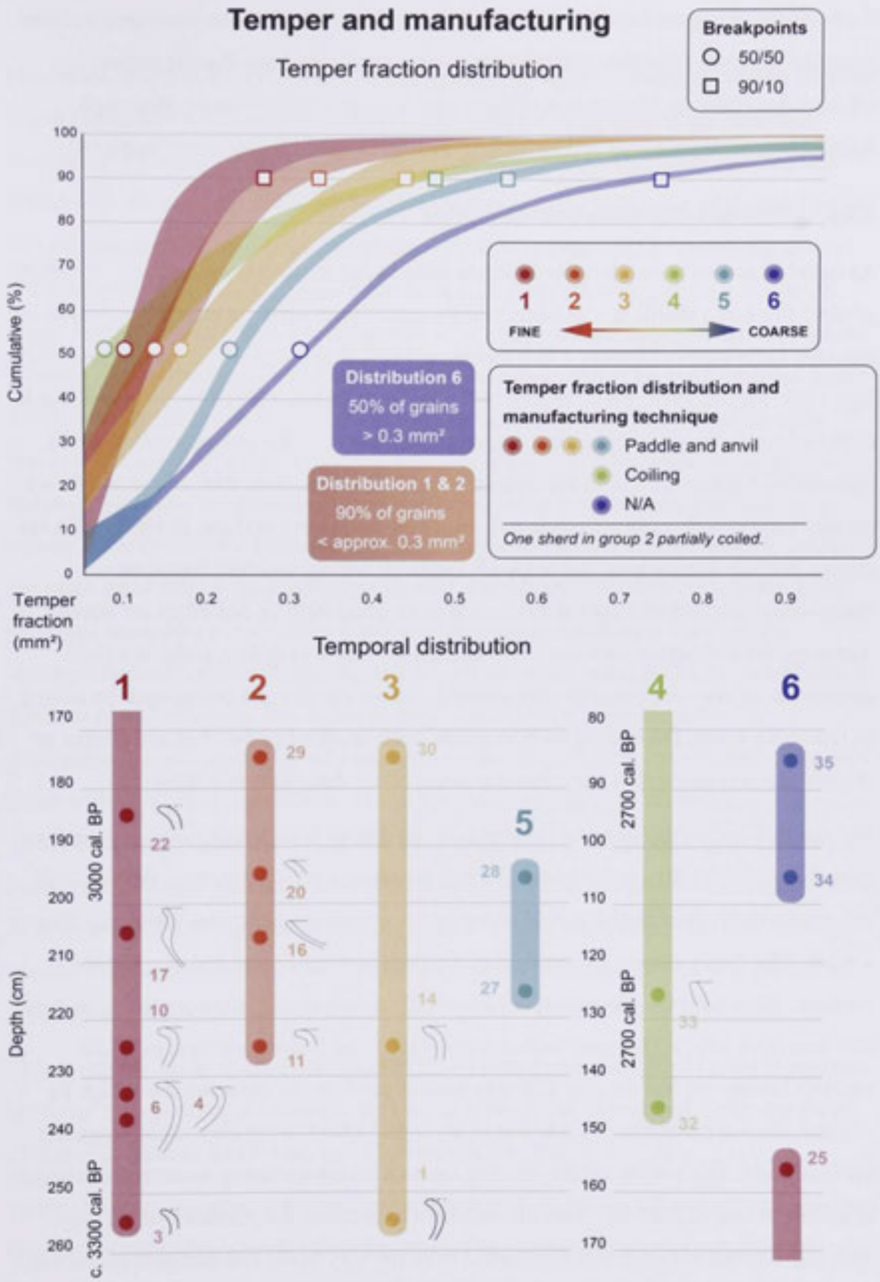


Figure 49. Chart of tempering and manufacturing techniques in studied sherds from Unai Bapot. Upper chart shows amount and size of added temper. Lower chart shows types of sherd and temporal distribution of different manufacturing methods.

Furthermore, the manufacturing traits seen in the Bapot sherds were compared to those recorded in sherds from four different Neolithic sites in the Indo-Pacific region: Chaolaiqiao, Taiwan; Nagsabaran, Philippines; Ulong, Palau; Ambitle, Bismarck Archipelago which have an approximately similar in age to Bapot (See Chapter 8).

7.6.6. Surface treatment and decoration

As noted in earlier research in the Mariana Islands, the most common surface treatment of early Pre-Latte sherds is a red-slip, and the majority of early ceramic assemblages are reported to be slipped (Spoehr 1957; Reinman 1977; Thompson 1979; Leidemann 1980; Ray 1981; Moore 1983, 2002; Butler 1995). At Unai Bapot, 81% of the sampled sherds (8304 bodysherds and 770 rim and diagnostic sherds) have the characteristic red-slip reported by Spoehr (1957). In the earliest part of the excavation, 95% of the sherds are surface treated with a characteristic red colour on the pottery surface. Butler (1995) has argued that the terminology 'red-slipped' might be wrong, and that, based on microscopic inspections, most sherds could more accurately be described as 'filmed'. Although the distinction between a *slip* and a *film* is hard to define, a slip is a fluid suspension of clay and contains clay minerals whose fluidity can be changed by adding or removing water. Depending on how much water is added to the clay, the thicker or thinner slip you get, with a very thin slip being better described as a 'film'.

My research shows that most of the sherds studied from Unai Bapot have on them less than the typical 30-80 μm thickness of a slip (Santacreu 2014), therefore the very thin red colour layer, as in Butler's 1995 observation, is perhaps better described as a film or a wash. This thesis retains the word 'slip' for both washed/filmed and true slipped surfaces. Slips used for decoration are commonly coloured and often contain colourants like iron (Rye 1981). This may be the case for the Unai Bapot ceramics, as pXRF analysis has shown that the clay that was used to produce the ceramics has a high Fe content. Slips are commonly made out of the liquid added to the clay while preparing the clay paste. The potters decant the clay through levigation using water and containers to eliminate coarse fractions from the sediment to increase the plasticity of the clay. This could result in fine-grained sediment from the clay being retained and mixed with the residual water, which could then be used as a slip (Santacreu 2014:68). At Unai Bapot, several lumps of red ochre were found at various levels of the excavation, and it is also possible that ochre mixed with water or some other liquid (or fat) could be the source of the red colour on the ceramic vessels.

Decorated ceramics are rare in Mariana assemblages. Only 37 decorated sherds from the Bapot excavation were recorded, which is less than 0.1 % percent of the material. Because of the rarity of decorated sherds, all decorated fragments were sampled and included in the analysis. For a comparison, Achugao at the west coast of Saipan yielded 147 decorated sherds in a total assemblage of 3350 sampled sherds suggesting around 4% of sherds in the earliest layers were decorated (Butler 1994), and from House of Taga, Tinian, around 350 decorated pieces were found in a 90 square metre excavation (Carson 2014). The Bapot décor consists of three forms: rim or lip modifications such as notching, pinching or stamping, and incising and stamping on neck and shoulder portions. Decoration in the earliest assemblages often consists of incised and dentate stamped/impressed elements in complex patterns, often lime-infilled. Rim stamping occurs sometimes in the Intermediate Pre-Latte period and the late pre-historic ceramics are often decorated by lip notching or incised patterns (Butler 1995:173). In the Early Pre-Latte assemblages two distinct styles of decoration are known. They are the *Achuago Incised* and *San Roque Incised* decorative styles, named after two early sites at the west coast of Saipan. The Achuago Incised style has a complex pattern of predominantly rectilinear incised patterns with the zones in between the major elements filled with very small punctations. The punctations are placed in diagonal, orthogonal or chevron patterns (Appendix 1:63). The other style, named San Roque, is decorated with bands of curvilinear garlands made by linking incised arches with small stamped circles or large punctations (Appendix 1:62-63) (Butler 1995:356). Butler finds that Achuago Incised is more common than the San Roque Incised; Achuago Incised was present in around 1 of 56 vessels, and San Roque was 1 in 447 vessels (Butler 1995:200).

Sherds of both these styles were found at Bapot (see Appendix 1:62-63), but in contrast to Butler's excavation at Achuago, the ratio at Unai Bapot is reversed. Only one sherd of Achuago Incised was found, and 18 sherds of San Roque Incised.

At the Achuago excavation it is unclear whether both styles are fully contemporaneous, or if one of the styles is earlier than the other. They consistently co-occur, but San Roque Incised seems to persist longer than Achuago Incised (Butler 1995:200). In the 1992 excavation by Erwin Ray at Akitsu Shoji, San Roque, Saipan, both styles were recovered in deep redeposited sands. At that excavation, San Roque Incised was the dominant style and only a few Achuago Incised sherds were found, mostly in the deepest layer. San Roque Incised co-occurs with Achuago Incised in a few instances, but San Roque Incised is consistently found in levels above those were Achuago Incised occurs (Butler 1994:31-32). Carson suggests that Achuago Incised is an earlier type than San Roque, but in his 2005 excavation of Unai Bapot, neither type was found in the earliest levels of the excavation, but in the second and the third cultural layers (Carson 2008, 2014).

The excavation of Unai Bapot, Block A, recovered one sherd of the Achuago Incised type and it was found in the very earliest layer at 250-260 cm below datum. Eighteen sherds with San Roque Incised decoration were found, with the first sherds at 240-250 cm and continuing up to 190 cm, although the majority of the sherds were in the lowest cultural layers (250-220 cm). The sequence appears to verify Butler's argument that San Roque Incised lasted longer as a style than Achuago Incised did. Based on the single Achuago Incised sherd it is not possible to draw any strong conclusions about which of the types is the oldest, but it is clear from the 2008 excavation at Unai Bapot, that both are part of the very earliest prehistory of the Mariana Islands.

Other décor elements found on ceramics at Unai Bapot that are not either Achuago Incised or San Roque Incised, include incised, grooved, dentate stamped, punctate, circle stamped, shell impressed, and paddle-marked sherds (see Appendix 1:61).

As already mentioned, finds of decorated ceramics from the Earliest Pre-Latte Period are very rare at every site in the Marianas. At Unai Bapot, Block A, only 37 decorated sherds in an assemblage of 19 307 sherds were retrieved. Of these 37 sherds, 26 are from the first 400-300 years of settlement dated to ~3200/3000-2800 cal BP. The 2005 excavation yielded 16 decorated sherds from approximately the same time frame (Carson 2008: 121, Table 1). A hypothetical assemblage from Unai Bapot based on the decorated sherd number would be minimal. The fact that decoration was limited to so few vessels would presumably have made them significant in some sense. The rarity of decorated vessels suggests that they were only used in certain contexts, and may have been handled by only a few people in the society. Perhaps, different types of Achuago Incised and San Roque Incised vessel were associated with different social units (Butler 1995:200). At this point, with only a few sherds found at Unai Bapot and other sites, this is speculation.

Even though very few decorated ceramics have been found in the Marianas, the early dentate-stamped and circle-marked red-slip ware has invited comparisons between the early cultures in western Micronesia and Lapita culture in the Bismarck Archipelago. An origin for the Marianas pottery in northern Luzon has been proposed (Carson *et al.* 2013 Carson 2014; Hung *et al.* 2011). Several points have been made about the decorated Mariana ceramics and their origin (see Spoehr 1957; Solheim 1984, Spriggs 2007, 2011a; Bellwood 2007, 2011; Hung 2008 and Hung *et al.* 2011), but most studies have involved superficial comparison of a few decorated sherds from a variety of contexts, and as Craib (1999:482) has noted: "general parallels with the early decorated ware in the Marianas can be found within several areas of southeast Asia. Virtually anywhere between Taiwan and southern Indonesia will exhibit similar pottery designs". The main argument held by advocates for the northern Philippines being the homeland of the first settlers of the Mariana Islands, apart from some similarities in décor, is the site chronology (Hung *et al.* 2011; Carson *et al.* 2013). An early chronology for Mariana Islands 3500 cal BP (or earlier) as proposed by Carson and Kurashina (2012:426-427; see also Carson 2014:34-35) argues that the only Neolithic sites in ISEA with red-slipped pottery with incised and punctate-stamped decor are found in the northern Philippines (especially the Cagayan Valley) and that there could be no other ancestor for the colonisers of the Mariana Islands (Hung *et al.* 2012). This thesis will argue (see Chapter 10) that the early dates for the colonisation of the Mariana Islands are 200-400 years too old and that leaves the whole of ISEA as a possible origin point for the first colonisers of the Mariana Islands.

7.6.7. Vessel forms/typology

Reconstruction of vessels is a common praxis in archaeological investigations, and so general reconstruction and presentation guidelines have been developed (see Sheppard 1956; Rye 1977; Gibson and Woods 1997). The ceramic material from the earliest layers from Bapot is fragmented and many sherds are smaller than 2 cm^2 in area. Therefore, the analysis of different vessel forms in this research is restricted to the study of rim sherds (n=737) and diagnostic shoulder/body sherds. Only rim sherds of adequate size and with recognisable attributes were used since more than one vessel form may be represented by the same rim type. Since several rim sherds were almost identical and probably belong to the same vessel, only diagnostic sherds were drawn and duplicate rims were sorted to a vessel type.

This procedure indicates the range of vessel forms and illustrates ceramic change over time. There are relatively few different vessel forms reported for the Mariana Islands and in general they exhibit simple forms, however, vessel forms changed significantly over time (See Appendix 1:53-60). The early "red ware" vessels were dominated by a shouldered/ carinated jar/bowl, which most often had an everted rim and in-sloping shoulder. Below the shoulder, the vessel was often globular. The vessels were relatively small, with orifice diameters of 10-22 cm. Less common was a hemispherical bowl with very thin walls 5-7 mm thick. After several centuries, there was a change towards larger and thicker jars and bowls with the shoulder gradually disappearing and the openings becoming less restricted. By 2000 BP, the ceramic assemblage was dominated by a large flat-bottomed vessel, although some hemispherical bowls were still used. About 1500 BP there was a shift again toward a thin-walled hemispherical bowl and an oval bowl. Between 1500-1000 BP, bowls with a slightly thickened incurved rim appeared, and vessels became larger. By around 1000 BP, the *latte* ceramic complex had developed and the dominant vessel form was a deep (~30 cm) globular or oval pot with a thickened incurved rim. A few finds of bowls and robust straight-sided pans were also made from this period (see Figure 50 and Figure 51; Hunter-Anderson and Butler 1995; Butler 1995).

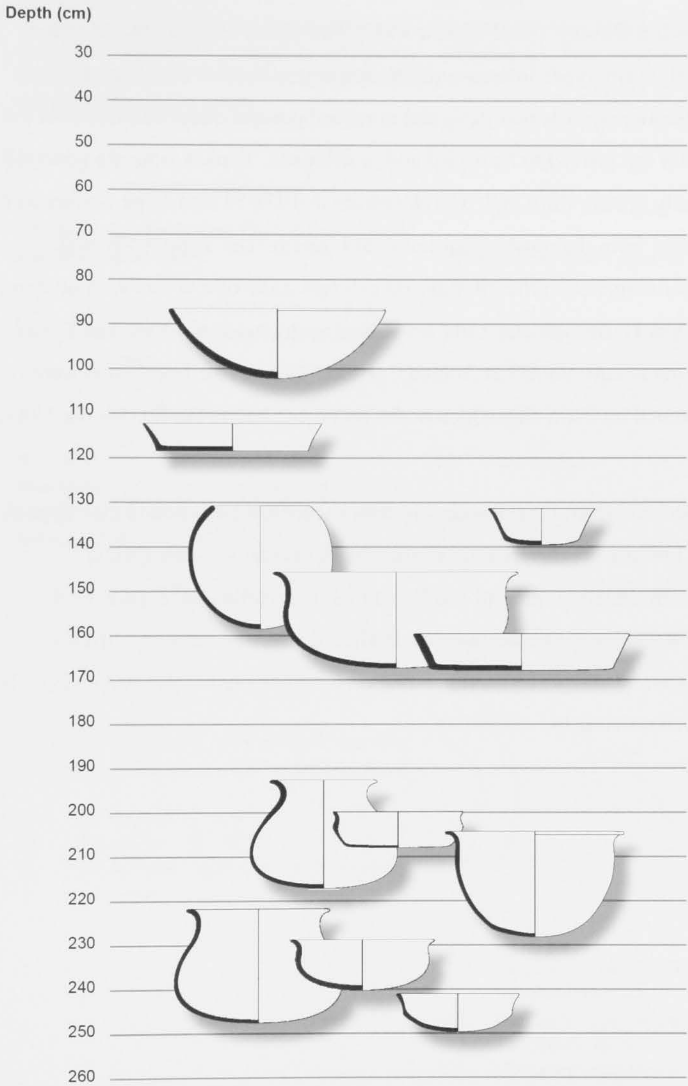


Figure 50. Chart of changes in vessel forms through time at Unai Bapot.

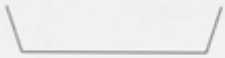
7.6.8. Rim form/Rim profile

Earlier ceramic studies (Moore 1983; Spoehr 1957; Thompson 1979) in the Mariana Islands have classified rim types into two major categories: Type A and Type B rim forms. The classification system was designed to record general observations about the rim, but the division has proved to be useful and is still used. Type A rims are generally associated with early pottery (although Marck reports in 1978:53 that Type A rims were sometimes recovered from the most recent levels at Laulau). The Type A rim was formed from the convergence of the interior and exterior walls of a vessel with no extra clay added. The Type B rims are generally associated with later prehistory, but Type B rims were also found in early layers at Achuago (Butler 1995:178). These rims were intentionally thickened by extra clay added at the lip or just below the lip (Moore 1983; Butler 1995).

For the ceramic material from Unai Bapot, rim forms were not categorised into Type A and Type B rims, but into six different categories (with several sub-categories) depending on the rim direction, the rim profile and the lip profile (see Figure 51 & Appendix 1:65-67). This was to make a more detailed distinction between different vessels, although several categories could be placed within the two Type A and Type B rim forms identified previously.

D) Direct

Unrestricted vessels with direct vertical or steep rim/wall orientation and varying rim and lip profiles. Mostly parallel or converging rim profile and rounded or flat lip profile.



The direct rim sherds were divided into two sub-groups based on size:

D1: Thin ware (wall thickness 5 – 11 mm).
D2: Thick ware (maximum wall thickness > 11 mm).

B) Bowls

Unrestricted vessels/open shallow bowls with incurving rim direction and varying rim and lip profiles.

The direct rim sherds were divided into two sub-groups based on size:

B1: Thin ware (wall thickness 3 – 5 mm).
B2: Thick ware (wall thickness ≈ 7 mm).

I) Incurving

Restricted vessels with incurving rim direction, varying rim profile and in most cases rounded or flat lip profile.

I1 I2

The direct rim sherds were divided into three sub-groups based on rim angle or wall thickness.

I1: Rim angle ≈ 25 – 50°.
I2: Rim angle ≈ 60 – 80°.
I3: Thick ware (maximum wall thickness > 11 mm).

O) Outcurving

Restricted vessels with outcurving rim direction and varying rim and lip profiles.

O1 O2 O3

O1: Parallel or near parallel rim profile and rounded lip profile.
O2: Gradually converging rim profile and rounded lip profile.
O3: Gradually converging rim profile and pointed lip profile.

Figure 51. Categorisation of rim sherds from Unai Bapot.

Rim direction/orientation was determined by orientating the lip to a horizontal plane until the gap between the lip and the surface disappeared. This method is a standard archaeological procedure (Shepard 1956, 1963; Glover 1986; Summerhayes 2000). All rim sherds from Bapot were examined and all sherds large enough with distinct features were drawn in cross-section at 1:1 scale (See Appendix 1:4-51).

Where several sherds were identical, only one drawing and description was made and (See Appendix 1:35-51 and 68-86) gives the total number of rim sherds of a vessel type. In all sherd profile illustrations found in this thesis, the outer vessel surface is oriented toward the left.

7.6.9. Diameter

Rim diameter measurements were made on all rim sherds that were large enough, generally where a sherd or joined sherds made up 5-10% of the total rim orifice. The diameter measurements were made on the lip of the vessels using the curvature of the sherd to produce a circular segment from which the diameter could be calculated. This means that the measured diameters are maximum orifice widths. Rim orifice diameters in this study are consistent with those recorded in earlier studies by Hunter-Anderson and Butler (1995), Butler (1995), and Moore (1983), and vary between 10-45 cm (mean orifice diameter ~20 cm) for the first 500 years of occupation (3200-2700 cal BP), 15-37 cm (mean orifice diameter ~27 cm) for the next 500 years (2700-2200 cal BP), 21-30 cm (mean orifice diameter ~30 cm) for the next 600 years (2200-1600 cal BP), and 17-40 cm (mean orifice diameter ~30 cm) for the next ~600 years (1600 cal BP to Latte Period).

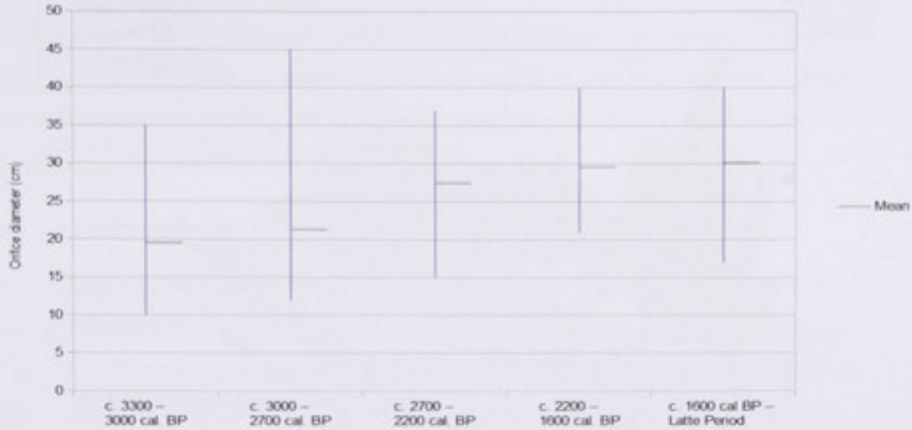


Figure 52. Orifice diameter of different vessels from Unai Bapot.

7.6.10. Body sherd thickness

All body sherds >1 cm in greatest length from units 1-3 of the north face of the Bapot, Block A excavation were measured for wall thickness. The sample of 8304 sherds was measured with digital callipers. Figure 53 shows the mean body sherd thickness for sherd samples by 10 cm intervals. There is a significant change in wall thickness over time in the ceramic assemblage, with older ceramics much thinner than the ones found in more recent layers (Figure 54).

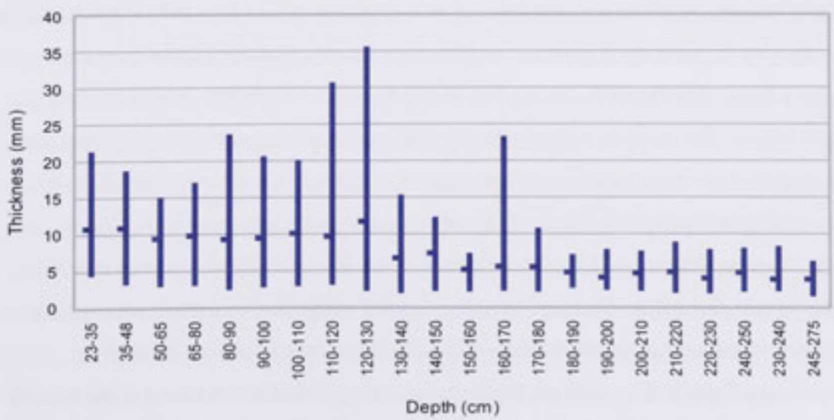


Figure 53. Maximum, minimum and mean wall thickness of 8304 body sherd by 10 cm excavation interval.

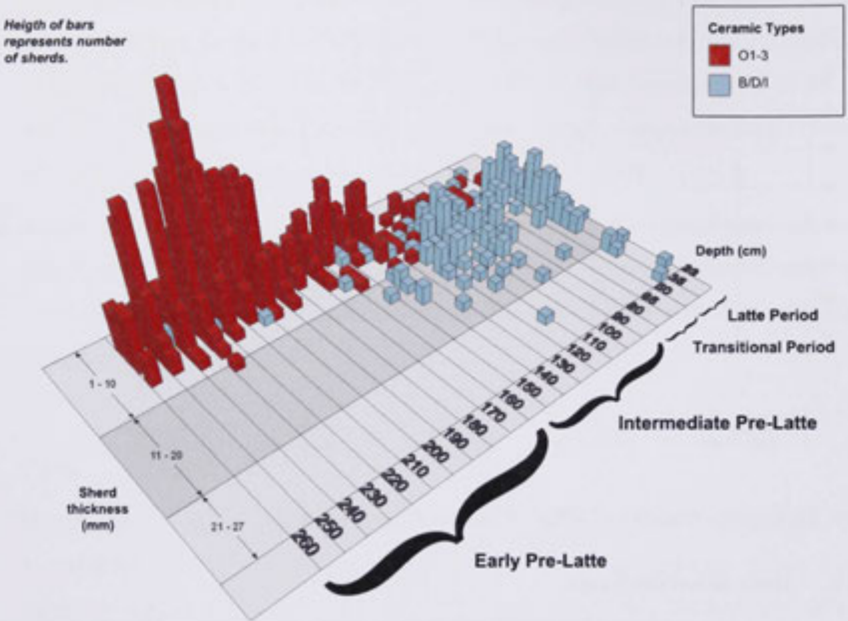


Figure 54. Sherd thickness and different rim types. Red bars represent thin Early Pre-Latte Outcurving 1-3 (O1-3) type sherds and blue bars represent later and thicker Bowls/Direct/Incurving (B/D/I) type sherds.

7.6.11. Firing

A small scale re-firing test of ceramic sherds was carried out at the Ceramic Laboratory in Lund University. There are several uses of such analysis (see Rye 1981), but the main aim of my re-firing study was to assess difference in manufacturing techniques of ceramics from early Bapot layers, and of sherds from four Neolithic sites in the Indo Pacific region. The analysis helped identify how potters chose material at different sites and what kind of firing techniques were applied to clays. Seven sherds from different layers of Bapot (three Early Pre-Latte sherds tempered with calcareous sand, three sherds from the Transitional Period tempered with a mix of volcanic and calcareous sand, and one sherd from the Latte Period tempered with mainly volcanic sand), were compared to each other and then compared with five sherds from four other sites: Chaolaiqiao, Taiwan; Nagsabaran, Philippines; Ulong, Palau and Ambitle (Feni Island) in The Bismarck Archipelago. The results are displayed in (see Appendix 1:120; 158; 189; 212; 243 and Table 25, 41, 56, 66 and 79).

7.7. Non-ceramic artefacts

While ceramics are the primary focus of this thesis, the Block A excavation recovered many non-ceramic artefacts made of stone, bone, and shell. The large quantity of stone and shell artefacts means that only a summary description can be given here and a detailed report of the items will be published elsewhere.

7.8. Lithic artefacts

In the Block A excavation, a total of 7922 g of lithic materials was recovered from the stratigraphic layers, (as shown in Figure 57 and 59). A preliminary analysis identified a range of artefact types (see Appendix 2:37). Artefacts included flakes and debitage from chert, basalt and altered sandstone, sling stones (n=4), stone adzes and adze fragments (n=22), net sinkers/pendants (n=3), round stones interpreted as anvil stones for pottery production (n=2), lithic cores or retouched flakes (n=5), and two pounders. Of the latter, one pounder is made of coral (Appendix 2:17, cat.nr 133:3) and one in coarse grained rock (Appendix 2: 153, cat.nr. 153:1).

Most of the stone adzes/adze fragments (15 out of 22) were present in the deeper layers between 260-150 cmbd. A cache of three adzes recovered from layer VI at 220-230 cmbd were in altered sandstone (Clark *et al.* 2010:25-26). Sandstone or altered sandstone/ amorphous rock is the most common material used for adze manufacturing in the Early Pre-Latte period and 13/15 adzes were manufactured in this material. From layer V at a depth of 150 cmbd, two adzes of light grey volcanic rock were recovered. One large sub-lenticular volcanic adze (see Appendix 2:13 cat.nr 99) measured 20 cm long by 10 cm wide and weighed ~1 kg, with the smaller adze weighing 478 g (see Appendix 2: 12cat.nr 97:3). The choice of altered sandstone for manufacturing adzes is curious since finds of harder volcanic material from the same layers indicate that there was harder material available for tool manufacture. Two artefacts, one round stone of unknown material and one oval of coral (Appendix 2:20, cat. nr 143 and 2: 6, cat. nr 22:6 respectively), are interpreted as anvil stones used in pottery manufacturing. Extremely similar stones are reported from the pottery-making village Mare Gam, Mare, Halmahera, by Pétrequin and Pétrequin (2006:355-356, Plate: Man 88 755). Microscopically-visible traces of what might be red-ochre, or more likely clay containing a high amount of iron oxide Fe_2O_3, were observed on the artefact (Appendix 2:20, cat. nr 143) (see Figure 55) but further chemical tracing research is needed.

Figure 55. Possible paddle and anvil stone with potential red ochre, Cat nr. 143 200-210 cmbd.

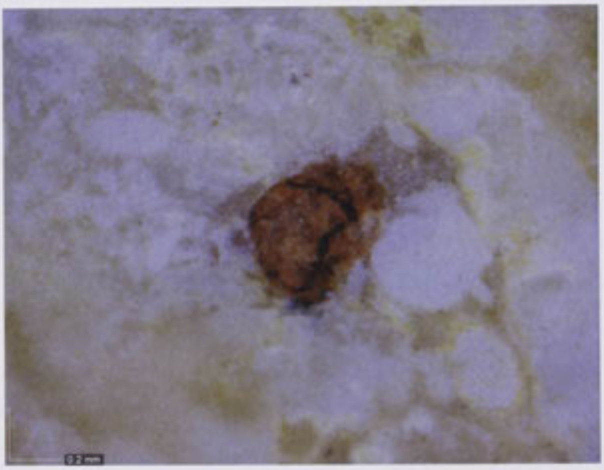


Figure 56. Microscope photograph of potential red ochre or red clay inclusion with high amount of iron oxide Fe_2O_3. Scale = 0.2 mm.

A thin section petrographic study of 24 stones and artefacts was made by Geoff Hunt (see Appendix 2: 45). The study showed that thin sectioned lithics were probably indigenousto the Mariana Islands. The large quantity and diversity of lithic artefacts from a range of different sources indicates that the first settlers of Unai Bapot immediately started to explore the environment, and quickly began making stone artefacts with locally available stone from a range of sources. At Unai Bapot the early settlers seem to have favoured stone for adze manufacturing as *Tridacna* adzes are entirely absent from Early Pre-Latte layers. This was also the case at Achugao Point (Butler 1994), Chalan Piao (Moore *et al.* 1992) and Unai Chulu (Craib 1993). Carson (2014) reports a *Tridacna* adze made from the hinge section in an early layer from House of Taga, Tinian and also an adze manufactured in *Cassis cornuta* (Mike Carson, personal communication, Jan. 2014).

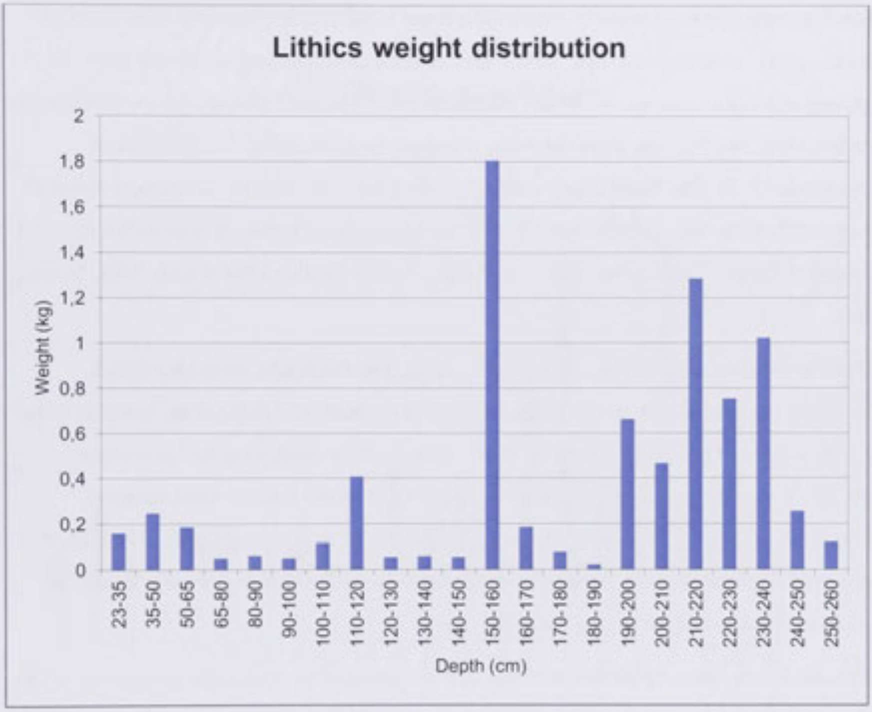


Figure 57. Lithics weight distribution. The high peak at 150-160 cm is due to a large adze with a weight of 1 kg.

7.9. Shell artefacts

Worked shell is by far the most common non-ceramic artefact recovered at Block A. The shell artefact assemblage consists of 228 artefacts of different types, and includes a substantial collection of shell ornaments and tools (see Appendix 3 and Figures 58, 59, 60, 61). Shell ornaments included a number of types of beads, the most common of which were small cylindrical beads (see Appendix 3:8). These appear to have been manufactured by grinding the apex of small conically shaped gastropod shells flat on both ends to form a disk. Holes were then drilled through the centre of the small disk to form a bead (O'Day 2015; Mirani Litster personal communication, Feb. 2015). Also common were ground *Cypraea moneta* shell beads with the dorsal part removed and the bottom portions of the shell ground flat so that the interior portion of the shell was exposed (see Appendix 3:9).

Shell ornaments from the early portion of the sequence at Unai Bapot also included small ground *Cypraea moneta,* small cylindrical beads, three pendants made from the dorsal portions of *Cypraea* spp. shells, disc-shaped pendants manufactured from the ground apex of *Conus* sp. shell (see Appendix 3:6), and several fragments of shell rings or bracelets, likely made from the body whorls of large *Trochus* or *Conus* shells (Appendix 3: 7). The Unai Bapot shell ornaments are very similar to artefacts reported from other Early Pre-Latte Period sites in the Marianas including Achugao Point, Saipan, Chalan Piao, Saipan, and Unai Chulu, Tinian (Butler 1994; Craib 1999; Moore *et al.* 1992).

Shell tools consisting of chisels, scrapers, adzes, and fishhooks were also found. Scrapers were most commonly made from bivalve shells of *Tridacna* sp, but also from *Cypraea* sp. O'Day (2015:98) notes that: "most bivalve shell scrapers have worn posterior, ventral, and anterior margins. These were likely formed from scraping vegetable matter while holding the valve by the dorsal margin and umbo. The author observed the use of bivalve shells with similar ware patterns being used in Fiji to process *Pandanus* sp. leaves for making mats".

Several fishhooks were recovered from levels starting at 80 cmbd and continuing to the deepest cultural deposit in Block A. These included "J" shaped hooks made from pearl shell of the Pteriidae/Trochidae family (see Appendix 3:4), several possible pearl shell fishhook blanks (see Appendix 3: 12) and a possible shell point for a compound fishhook (Patrick O'Day. personal communication, 2015). Fishhooks and other types of fishing gear have been recovered from *Latte* Period, transitional and Early Pre-Latte Period contexts from various sites on Guam and the CMNI (Amesbury and Hunter-Anderson 2003). Several artefacts interpreted as abraders or perhaps chisels were made from large sea urchin spines, possibly from slate pencil urchin *Heterocentrotus* cf. *mammillatus*, or the pencil urchin. The abraders/chisels were made from grinding down the end of the spine creating a sharp round edge (see Appendix 3:5).

Shell adzes were also recovered. These were mainly made from the umbo, or hinge portion of *Tridacna* clams (see Appendix 3:3). *Tridacna* adzes were only present in the upper levels of the stratigraphic sequence and were entirely absent from the Early Pre-Latte Period layers of Block A at Bapot 1. This was also the case at Achugao Point (Butler 1994), Chalan Piao (Moore *et al.* 1992) and Unai Chulu (Craib 1993). While *Tridacna* adzes were limited to the Latte period, a chisel-like tool made from a large bivalve shell was recovered from approximately 180-190 cmbd (see Appendix 3:11). This layer is dated to ~2900 cal BP.

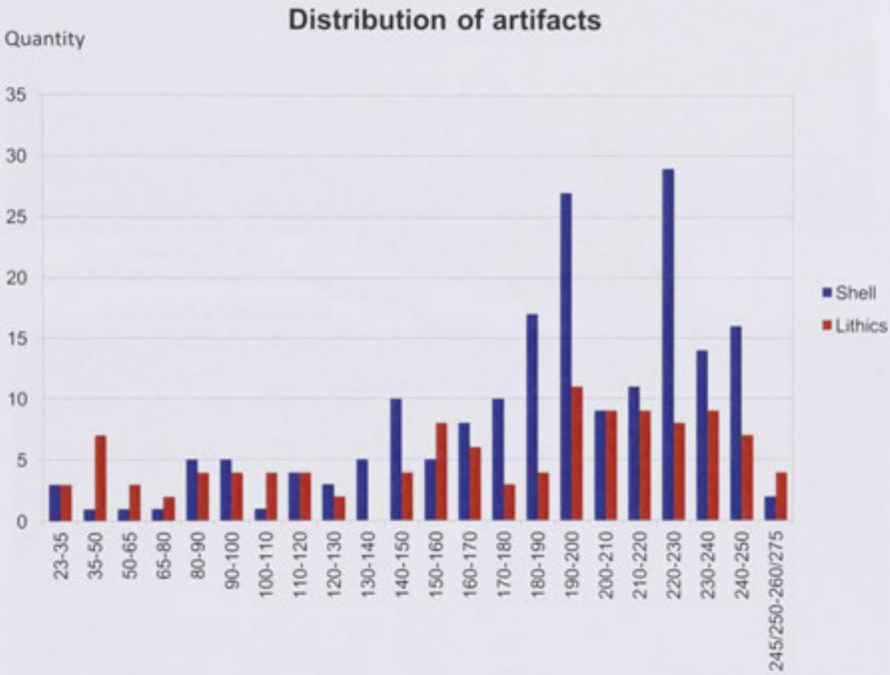


Figure 58. Chart of the stratigraphic relationship of marine shell and lithic artefacts, Unai Bapot.

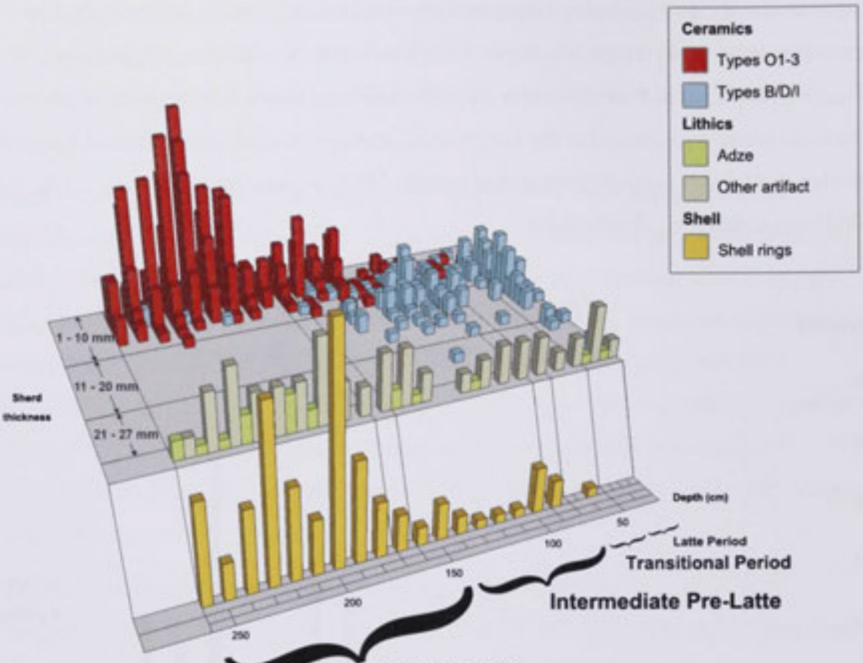


Figure 59. Chart of distribution of different material culture categories found at Unai Bapot, Block A.

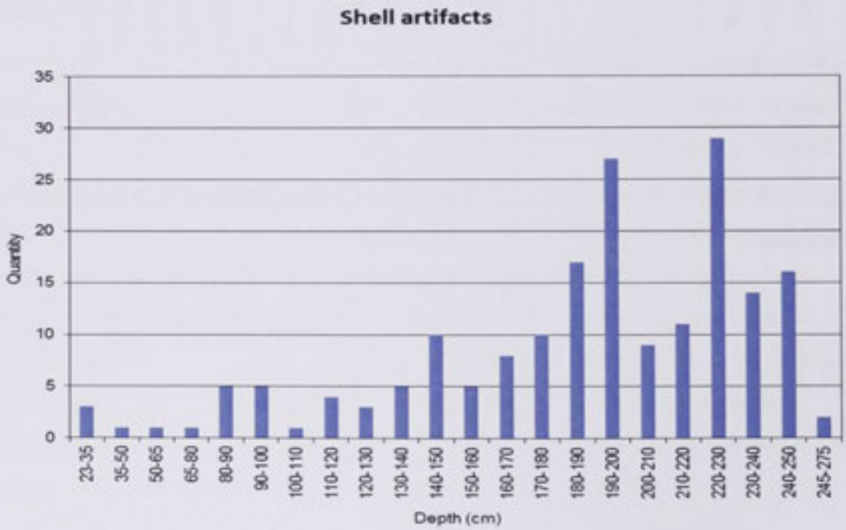


Figure 60. Distribution of shell artefact number by depth.

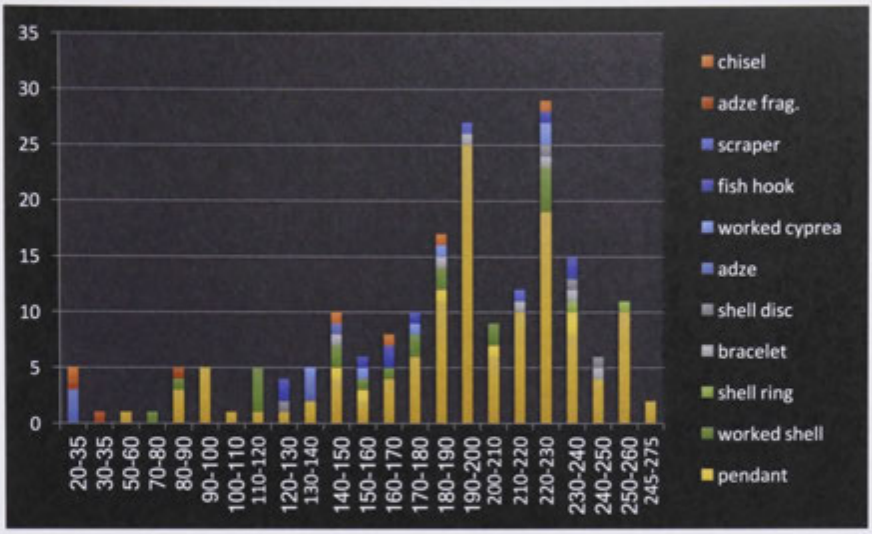


Figure 61. Distribution of different type of shell artefacts by depth.

Figure 62. Worked shell implement, interpreted by O'Day as a possible compound fishhook point. Catalog 143, Test unit 6, 200-210 cmbd. (After O'Day 2015:179).

7.10. Faunal assemblage

The excavation at Block A at Unai Bapot produced a relatively large faunal assemblage that included vertebrate remains and a large variety of invertebrates. The vertebrate remains consisted mostly of fish and bird bone from a number of taxa. Reptile and mammal bone was limited to only a few elements of small lizards (*Lacertilia* spp.), monitor lizard (*Varanus* cf *indicus*), rat (*Rattus* sp.), and fruit bat (Pteropodidae). Terrestrial invertebrates found at Block A included two species of land snail (*Pythia scarabaeus* and *Achatina fulica*) and a large assemblage of marine invertebrates (O'Day 2015:100-101).

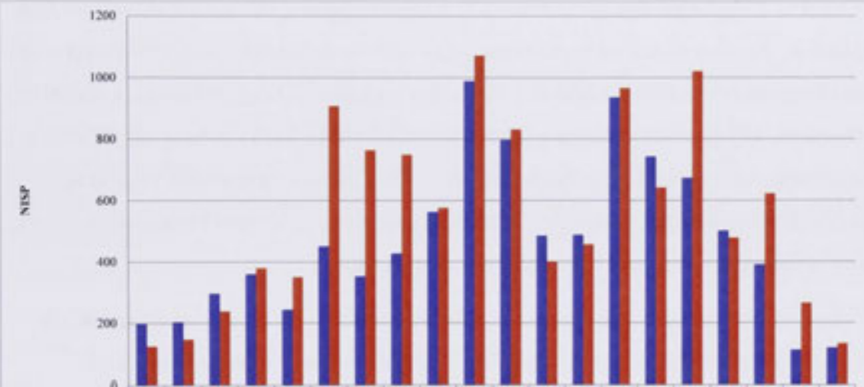
Detailed analyses of marine invertebrates recovered from Block A has been made by Patrick O'Day. The results of his analyses are forthcoming in his unpublished dissertation and a summary is presented here. The invertebrate subsample included all of the invertebrate remains from units 1, 4, and 6 due to the quantities of shell recovered

The sample of invertebrate remains analysed by O'Day had a 'Number of Identified Specimens' (NISP) of 21 051, a weight of 43 kg, and included coral (Anthozoa), sea urchin (Echinoidea), gastropod shell (Gastropoda), bivalve shell (Bivalvia), beach shell, and indeterminate shell. Only two fragments of coral were recovered which accounted for less than one percent of the assemblage. Gastropod shell accounted for 44 percent of the assemblage, bivalves comprised 53 percent, the sea urchin *Heterocentrotus* cf. *mammillatus* one percent, and beach shell accounted for two percent of the total assemblage. O'Day found that many shells were whole and he was able to identify them to species level. Several broken and fragmented specimens also displayed attributes which allowed identification (O'Day 2015:101).

Table 8. Total counts and weights for invertebrate remains courtesy of Pat O'Day (2015).

Taxa	NISP	% NISP	Wt. (g)	% Wt
Anthozoa	2	<1%	14.40	<1%
Gastropoda	9 328	44%	18 910.80	44%
Bivalvia	11 128	53%	22 970.14	53%
Heterocentrotus cf mammillatus (Sea Urchin)	172	1%	180.60	0%
Beach shell	373	2%	806.40	2%
Indeterminate	48	0%	103.50	0%
Totals	**21 051**	**100%**	**42 985.84**	**100%**

There was a difference in the frequencies of gastropods and bivalves through the sequence (see Figure 63). Bivalves were more frequent in earlier layers and gastropods were only slightly more frequent in younger layers. The shift from higher frequencies of bivalve species to higher frequencies of gastropod species occurs late in the Pre-Latte, or Transitional Latte Period (2500 cal BP to 1600 cal BP). The same trend has been documented at Chalan Piao on Saipan (Amesbury *et al.* 1996) and at several sites on Guam (Amesbury 2007; Amesbury 1999; Graves and Moore 1985; Leidemann 1980), but usually occurs later, most often after the start of the Latte Period (O'Day 2015).



	65	85	96	104	113	122	130	140	153	160	171	181	190	200	210	220	230	240	250	260
NISP Gastropod	198	204	297	360	244	451	353	427	563	989	797	485	488	936	743	673	501	390	111	118
NISP Bivalve	124	147	239	380	351	908	764	750	576	1072	832	401	457	966	642	1021	478	623	265	132

Figure 63. NISP frequencies of gastropods vs. bivalves plotted according to depth after O'Day (2015:182).

7.10.1. Vertebrate remains

Bones from fish, reptiles, birds, and small mammals were recovered during excavation. Most of the bones were small and consisted of fragmented elements. Very few specimens were identifiable beyond class (Chondrichthys, Osteichthys, Reptiles, Aves, or Mammalia). Bones from marine fish were the most numerous followed by bird bones. Bones from reptiles and mammals were rare in the assemblage.

Detailed analyses of fish vertebrae recovered were also made by Patrick O'Day and a summary of his results is given here.

A total of 834 identifiable specimens of fish bone weighing 129 g were recovered from Block A. The fish bones were small and often heavily fragmented and 95% could only be identified to class (Osteichthyes). This class includes all bony fishes and consists of 45 orders, 435 families, and some 28 000 species (O'Day 2015). A total of 37 fish bone specimens were identified to the family level. They included parrot fish (Scaridae), jacks, jack mackerels, pompanos (Carangidae), trigger or file fish (Tetraodontiformes), and surgeonfish, tangs and unicornfishes (Acanthuridae).

Terrestrial vertebrate remains accounted for a comparatively small percentage of the overall faunal assemblage, with only 229 bones. Remains of reptiles, birds, and mammals from Block A were analysed by Trevor Worthy, Flinders University, and a summary of his analysis is given below.

A total of 215 bird bones were identified including eight species of land birds and three seabirds. A list of these species by NISP and percentage of NISP is in Table 9. Seabirds accounted for a small percentage of the avian assemblage with three identified bones, including a storm petrel (*Nesofregetta* sp.) and two terns (*Anous sp.*). Each represented less than one percent of the total number of identified bird bone. Land bird taxa (or shore birds; Stuart Hawkins, personal communication May 2015) were more diverse and consisted of a wading bird (Charadriiformes), a crake (*Porzana sp.*), flightless rails (*Gallirallus sp.* cf. *philippensis*), and numerous small birds (starlings, warblers, white eyes, honey eaters, and several small passerines). Indeterminate bird bone dominated the avian assemblage with a total of 119 specimens accounting for 55 percent of the collection. Remains of the flightless rail were present throughout most of the sequence from 85 cmbd to 230 cmbd in stratigraphic layers II through to layer VII. The amount of flightless rail bones was greater in the lower layers 230-190 cmbd (as expected in an early colonisation site), although present to 85 cmbd. This is a common observation, seen at various early sites in Pacific Islands, where flightless birds were hunted after human arrival. The flightless rail, especially *Gallirallus* spp., survived in parts of the Mariana Islands for millennia but became locally extinct on Saipan. Survival of the rail after human arrival may be related to the lack of chicken, dog, and pig, combined with a 2000-2500-year delay in the introduction of *Rattus exulans* (Steadman 1999:319).

Table 9. Summary table of identified bird bone from Bapot, Block A, after Worthy (unpublished data).

Taxa	Common name	NISP	% NISP
Seabirds			
Anous sp.	Terns	1	<1%
Nesofregetta sp.	Storm petrel	1	<1%
Puffinus cf *carneipes*	Flesh-footed shearwater	1	<1%
Landbirds			
Charadriiformes	Wading birds	1	<1%
Gallirallus sp. cf *philippensis*	Flightless rail	73	34%
Aplonis spp.	Starling	8	4%
Meliphagid sp.	Honey eaters	3	1%
Passeriformes	Sparrows and small birds	3	1%
Acrocephalus sp.	Warbler	2	1%
Porzana sp.	Crake	1	<1%
Zosterops sp.	White eye	1	<1%
Myzomela sp.	Honey eater	1	<1%
Aves	Indeterminate	119	55%
	Total	**215**	**100%**

Two species of reptile were identified from ten bones. These included six bones of *Varanus* cf. *indicus*, or the mangrove monitor lizard, and four bones from geckos (Lacertilia). Gecko bones are found between 50 to 210 cmbd.

The bones from *Varanus* cf. *indicus* were recovered from 50 to 62 cmbd. Radiocarbon samples recovered from this depth produced a date of 1350-1280 cal BP. The *Varanus indicus* distribution is wide and ranges from Indonesia (Sulawesi, Moluccas, Aru Islands, Talaud, Irian Jaya, Timor, Halmahera), Papua New Guinea, Australia, Solomon Islands, Bismarck Archipelago, Caroline Islands and to the Mariana Islands (Cota

2008). *Varanus indicus* is a large lizard and may have been introduced to the Marianas in prehistory (G. Pregill, personal communication May 2014). Bones from *Varanus indicus* have been found in the earliest layers at Tarague and at Mangilao (Liston. 1996; Dilli *et al.* 1998), and also in cave deposits dated by associated material to the pre-European period (G. Pregill, personal communication May 2014). Although there is a Chamorro name (*Hilitai*) for the monitor lizard suggesting an ancient familiarity with the species, archaeological evidence for its pre-contact introduction is limited and requires further research.

Table 10. Summary table of identified reptile bone from Bapot. Block A.

Taxa	Unit	Depth (cmbd)	NISP
Gecko (Lacertilia)	7	50-60	1
Gecko (Lacertilia)	3	50-62	1
Varanus cf. *indicus*	7	50-60	6
Gecko (Lacertilia)	5	180-190	1
Gecko (Lacertilia)	3	200-210	1

Only four mammal bones from two species were identified. These were two rat (*Rattus sp.*) and two fruit bat (Pteropodidae) bones (Table 11). Rat is only present in the later portion of the Bapot sequence from between 49 and 90 cmbd. Radiocarbon samples from these depths produced dates that ranged between 1350-1280 cal BP and 2110-1930 cal BP.

The first date coincides with the onset of the Latte Period while the second date of 2110-1930 cal BP is a little older than expected. The introduction of rat to the Marianas is considered to be relatively late at ~1000 cal BP (Steadman 1999). Two species of rat including the Pacific rat (*Rattus exulans*) and the Asian house rat (*R. tanezumi*, sometimes referred as *Rattus rattus monsorius*) were introduced to Micronesia prior to European contact, but only the Pacific rat has so far been identified in archaeological contexts in the Marianas (Wickler 2004).

Two fruit bat (Pteropodidae) or flying fox bones were recovered from between 170 cm and 190 cmbd, corresponding with layers V and VI, and dated to 3160-2960 cal BP. Fruit bats were likely hunted and eaten throughout prehistory (Steadman 2006:503). Today fruit bats are highly prized food items and are extremely rare in the Marianas having been hunted to the point of extinction, with one species (*Pteropus tokudae*) recently extinct on Guam (Mickleburgh *et al.* 1992; Vogt and Williams 2004).

Table 11. Summary table of identified mammal bone from Bapot, Block A.

Taxa	Unit #	Depth (cmbd)	Count
Rattus sp.	8	49/50-65	1
Rattus sp.	3	78/83-90	1
Pteropodidae	1	170-180	1
Pteropodidae	7	180-190	1

8. Comparative sites

8.1. Chaolaiqiao

The Chaolaiqiao site is situated on a natural terrace about 50 m above sea level on the eastern coast of Taiwan, at 22° 50'N, 121° 11' E. The site was discovered in 2000 during an archaeological survey where fine cord-marked and red-slipped pottery were collected (Hung 2008:88). In April 2005, Hsiao-Chun Hung and Peter Bellwood from the Australian National University carried out a small excavation. A 2 x 1m square called pit 1 was excavated down to 90-100 cm, with an extension of 0.5 metre. Two AMS dates on charcoal from layer 3 gave dates of 3736±43 BP (WK-17011-AMS) and 3704±32 BP (WK-17011-AMS). Layer IV is a sterile natural layer of silt or sand of riverine origin (Hung 2008:89).

Figure 64. Map of Taiwan, and Chaolaiqiao and northern Luzon.

8.1.1. Ceramic

Approximately 20 kg of ceramics were recovered from pit 1, and 8 kg from the pit 1 Extension. All pottery from Chaolaiqiao is red ware except for a few black sherds which were probably fire-blackened. Using the SEM-EDS mineral identification technique, inclusions of pyroxene and plagioclase derived from andesite and basaltic andesite were identified. The Chaolaiqiao pottery assemblage contain rims, body sherds (some carinated), ring feet, handles and lids suggesting that the vessel forms included restricted jars and unrestricted bowls (Hung 2008:91). Four types of pottery decoration were present at Chaolaiqiao: red-slip, fine cord-marking, mat impression and painting. The painted motifs consist of repeated crosses and oblique lines on the outside of the vessel and on rims. Over 95% of the sherds belong to the plain slip red category and this category occurred through the whole stratigraphy. The most common jar forms at Chaolaiqiao (See Figure 65) are J7, a globular vessel with an obvious ridge around the inside of the lip and where the top of the rim is flat, and J12, which has a restricted rim, everted above the neck and concave on the inside of the rim surface (Hung 2008).

Figure 65. Reconstructed vessel forms, Chaolaiqiao.

8.1.2. Lithic and jade artefacts

Common artefacts found at sites from the Middle and Late Neolithic of eastern Taiwan are long narrow rods, often made out of Taiwan slate, often referred to as stone needles (although none have eyes). Their function is not known, but explanations of their use are sewing, pottery making or lithic production. At Chaolaiqiao, 15 such rods made of slate were recovered. Furthermore, eight grindstones of sand stone were found together with three flaked sandstone axes, the most common lithic tool in Neolithic Taiwan, usually referred to as axe-hoes. Four so-called Pebble Tools (a pebble, with a flaked cutting edge at one end and most often made out of sandstone and in some cases basalt), and one oval sandstone hammer were found. Finally, three pieces of cut nephrite, one polished, were found in the excavation. All derived from the Fengtian nephrite source in central Eastern Taiwan.

8.1.3. Other finds

No faunal remains were analysed from Chaolaiqiao due to poor preservation conditions in the acid soil (Hung 2008).

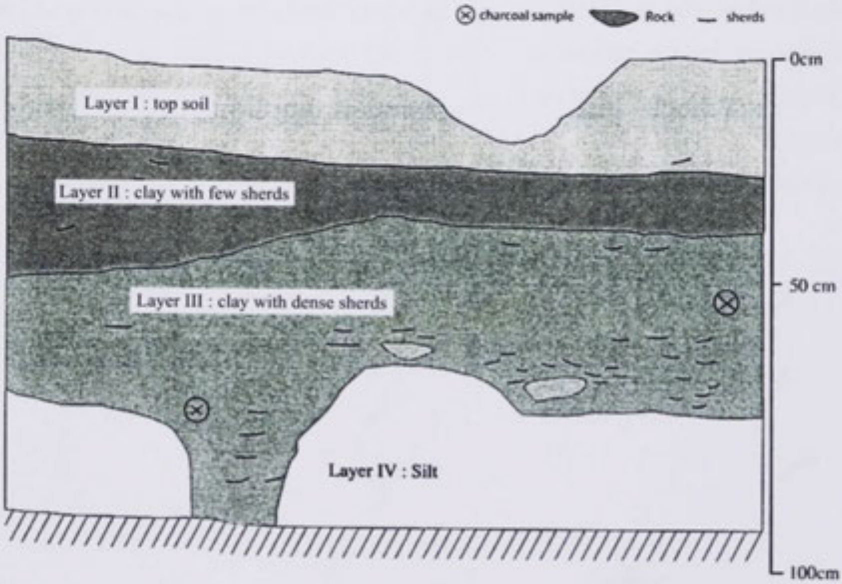


Figure 66. Stratigraphy Chaolaiqiao (After Hung 2008: Fig.4.13: 91)

8.2. Nagsabaran

Nagsabaran is one of more than 30 archaeological sites located along the Lower Cagayan River in Cagayan Province, on Luzon, Northern Philippines (See Figure 67). It is situated 22 kilometres from the mouth of the Cagayan River. First discovered in the 1990s andreported under the name Alaguia shell midden, it was renamed Nagsabaran by a Filipino-Taiwanese team that excavated the site in 1996 (Amano *et al.* 2013; Piper *et al.* 2009).

Figure 67. Map of Luzon and Nagsabaran.

The site consists of a large shell midden on the alluvial plain around 600 meters long, 70 meters wide and 1-3 meters deep.

In 2000-2001, eight test pits were excavated by a Filipino-Taiwanese team and a large amount of artefacts were encountered including pottery, polished stone adzes, stone flakes, a jade bracelet, clay penannular earrings, various ornaments of bone, tooth and shell, as well as stone and glass beads.

The Nagsabaran stratigraphy showed that the sequence of the site could be divided into two depositional series of layers. One lower alluvial silt deposit, containing red-slipped pottery, stone adzes, clay earrings and the jade bracelet, and an upper shell midden deposit characterised by black and red/brown pottery, glass beads and bracelets (Piper *et al.* 2009).

In 2004, a Filipino-Australian team led by Hsiao-Chun Hung (Australian National University), and Rey Santiago and Jose Santiago from the archaeology division of the National Museum of the Philippines excavated a 4 x 4 m square (pit 9) and a 2 x 4 m rectangle (pit 10; Hung 2008; 153, f). In 2009, four more trenches were excavated adjacent to Pits 9 and 10 (Pits 11-12), and to the southeast (pit 13) and towards the middle of the shell midden (pit 14; See Figure 68).

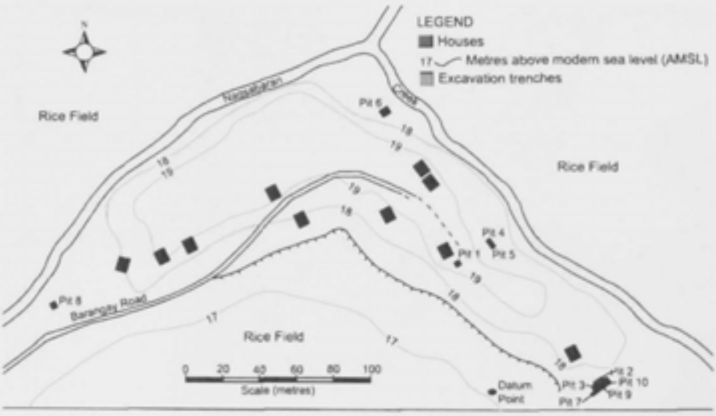


Figure 68. Map of Excavation at Nagsabaran (after Piper et al. 2009:691).

Pit 9 Nagsabaran

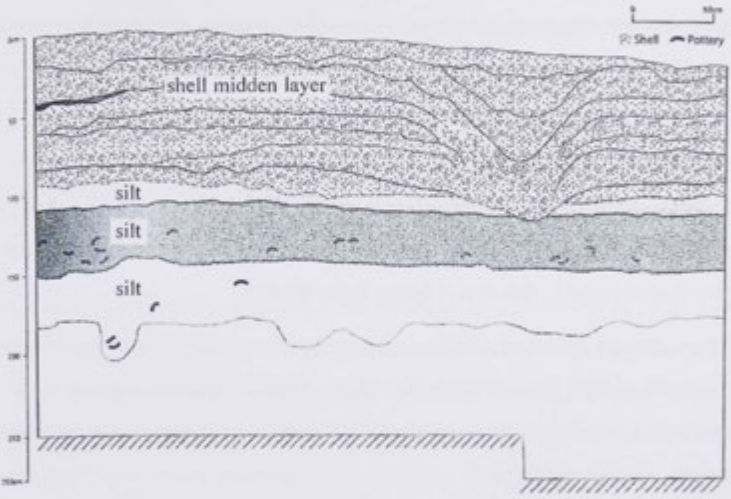


Figure 69. Stratigraphy pit 9. (after Hung 2008:157).

The chronological sequence and dating of Nagsabaran has proven to be very difficult to resolve, although excavations have revealed three distinctive layers as shown in Figure 69, a shell midden, a thin deposit devoid of artefacts and an underlying clay layer with early Neolithic artefacts (Amano *et al.* 2013:319).

The 2009 excavation recorded more than 60 postholes through the shell midden and into underlying clay deposits. Several of the postholes were more than 80 cm in diameter and 1 m deep. These postholes were not recognised during earlier excavations and the potential influence of the large and deep postholes for introducing material in overlying sediments to the oldest cultural deposit is critical for understanding the reversed order of many radiocarbon dates (see Figure 70) from the earlier Nagsabaran excavations (Amano *et al.* 2013).

In a supplement to a 2011 article in Antiquity, Hung *et al.* tried to clarify the disturbed and reversed stratigraphical order of the lower silt layers at the Nagsabaran excavation site. They wrote: "*The second series of layers consists of the alluvial deposits that lie immediately below the base of the shell midden. Apart from the upper surfaces with the postholes, these silty clay layers reveal no signs of actual human occupation – no midden, stamped floors, postholes or burials. It is these lower deposits that contain the red-slipped pottery [...]. These lower layers are clean silty clay, of alluvial origin, with* *charcoal only surviving where protected beneath sherds or in postholes. Our assumption is that these silty clay layers were deposited by fluvial action on the site of the future shell midden, bringing in cultural material from areas of Preceramic and Neolithic occupation which we have not yet located through excavation*" (Hung *et al.* 2011: 2).

Considering that there is no clear evidence of *in situ* human activity in the Neolithic deposits at Nagsabaran and that the lower silt layers produced dates with a span of c. 6500 calendar years, with many dates reversed, it seems almost impossible to detect when the red-slipped ceramic horizon at Nagsabaran started.

Hung *et al*. have chosen a total of six C14 samples that they apply to the Nagsabaran red-slipped ceramics (2011:3; see Figure 70). Three of the six dated samples derive from unidentified charcoal, one from a pig molar, one on animal bone and one from a fresh water shell, *Batissa childreni*.

Dating charcoal from unidentified wood species is always problematic since there could be unknown inbuilt age in the samples. Two of the accepted charcoal samples (GX-28379 and GX-28381) derive from Pit 7 from a depth of 1.6 m and 1.9 m, respectively. The samples are in stratigraphic order and dated to the Neolithic, but GX-28379, dated to 1454-1112 BC, was found in the same layer as NTU-3798, dated to 902-794 BC (and rejected by Hung *et al.*; see Figure 70), which causes some uncertainty about how old the dated layer is. The third accepted charcoal sample, GX-28381, has a large standard error of +-130 years and a calibrated age range with a large standard deviation of ca. 600 years, (2023-1417 BC), and it falls within the early ISEA Neolithic, ca.2000-500 BC (Amano *et al*. 2013:318).

Sample Wk-23397 derives from a domesticated pig molar from layer 14 in Pit 9, and is dated to 2567- 2299 BC. The layer directly beneath it (layer 15), has two samples, one on charcoal dated to 3337-2933 BC, and one on animal bone (Wk-19712) dated to 791-510 BC. The excavator rejects the older charcoal sample but accepts the younger bone sample.

Below the accepted bone sample in Pit 9 there are two rejected charcoal samples, one at 1.6 m, Wk-18059, which is much younger than Wk-19712 (1.5 m.), and one sample from 1.8 m, Wk -17756, which has a very similar date to Wk-19712 (see Figure 70).

The sixth and last accepted sample, ANU-13017, derives from Pit 14, 1.8 m, and is on freshwater shell, *Batissa childreni*, dated to 1873-1632 BC. All dated samples from Pit 14 are out of sequence, with the oldest date found in the very first silt layer (see Figure 70).

A study conducted by Dr Stewart Fallon, ANU, on modern samples of *Batissa childreni* does not show any significant marine reservoir effect, and all the Nagsabaran samples on *Batissa childreni* are dated with the same Intcal 09 database as the charcoal from the site (Hung *et al*. 2011:3).

Other research on *Batissa* fresh water shells has shown that the shell is problematic to date and results from Caution Bay, Papua New Guinea, indicate significant terrestrial 14C input into the shells of *Batissa violacea* because of their tolerance of brackish waters. The work at the Caution Bay archaeological site suggests a ΔR correction of ca. 200 years on B. violacea (Petchey *et al*. 2013:78). This could of course be less, as indicated by Dr. Fallon, as the exact ΔR correction is likely to be site specific, but more work seems to be needed on *Batissa* species. Petchey et al. do not recommend the use of *Batissa* species for the development of archaeological site chronologies.

The biggest problem with the dating of Nagsabaran is not the dates themselves; even if unidentified charcoal and possibly *Batissa* do have inbuilt age, they probably represent an approximate time frame of the Neolithic. The pig molar and the animal bone are better dated samples, although the pig tooth has a large standard deviation.

The real problem is that the archaeological material contained in the lower silt layers are not *in situ* within their primary context. This applies not only to the pottery, but also to the dated materials found in association with them (Swete Kelly 2015b). A domesticated pig tooth found out of sequence does not necessary prove that pottery found in the same layer is as old as the dated pig tooth. For example, the majority of the punctate stamped lime-infilled potsherds from Pit 9 that have been suggested as precursors to the dentate stamped pottery from the Mariana Islands, derive from depths of 1.5 m and 1.6 m, layers which have dates that span 127 AD to 3337 BC (see Fig.70; Hung 2008:171; Hung *et al*. 2011). Considering the likelihood of mixing due to the possible influence of floods or waterflows, there is a need for a conservative approach in assessing dates from the Nagsabaran site.

Dated material

- Charcoal
- Shell (*Batissa Childreni*)
- Animal bone
- Animal teeth

Sample status (Hung 2011)

- Accepted sample
- Shell midden associated
- Rejected sample
- Sample not discussed

	Separated pits – NW of P2/7/9		Adjoining pits – SE part of shell midden			Adjacent to P9	Towards middle of midden
Level	P1	P4	P2	P7	P9	P11	P14
1.3 m							ANU-13018 6380-6099 BC
1.4 m			GX-26704 895-699 BC		WK-23397 2567-2299 BC		
1.5 m	GX-26799 194 BC–AD 245		GX-26705 6065-4900 BC		WK-19713 3337-2933 BC WK 19712 791-510 BC		
1.6 m				NTU-3798 902-794 BC GX-28379 1454-1112 BC	WK-18059 21 BC-AD 127		
1.7 m						ANU-13016 1915-1749 BC	
1.8 m	GX-26800 AD 50–538				WK-17756 795-541 BC		ANU-13017 1873–1632 BC
1.9 m				GX-28381 2023-1417 BC			
2.1 m		GX-26711 799-417 BC					ANU-13024 897–801 BC
2.3 m	GX-26801 933 BC–AD 336						
2.4 m	GX-26802 918 BC–AD 346						ANU-13013 895-793 BC ANU-13014 797-546 BC
2.5 m	GX-26702-AMS AD 85–322						
3.1 m	NTU-3799 1886-1666 BC						

Figure 70. Table of dates from Nagsabaran after Hung 2008; Hung et al. 2011 (reported in BC/AD).

8.2.1. 2004 excavation

The 2004 excavation recovered numerous artefacts from the two different artefact-bearing layers. In the upper Shell Midden layer there were ceramics, baked clay pendants, glass beads, shell bracelets, animal bones (pig, deer, fish and dog bones) and human burials.

Artefacts from the lower silt layer (Spits 10-18) consisted of ceramics, baked clay spindle whorls, baked clay pendants, chert flakes, stone adzes of andesite and tuffaceous sandstone, grindstones, and a fragment of a jade bracelet. Furthermore, bones from pig, deer and fish was recovered from the silt layers.

8.2.1.1. Shell Midden layer

Ceramics

The pottery from the Shell Midden analysed in Hung's PhD thesis (2008) consisted of 757 rim sherds from Spits 1 to 9. Furthermore, ~27 kg of body sherds from pit 9, and ~26 kg from pit 10 were recovered. The dominant colour of the sherds is black, but a few were brown and reddish sherds were also noted. Vessel forms consisted of everted jars with a short and thickened rim and a round base. Some of these vessels were decorated with *pointillé* or incised lines.

The second most common vessels were bowls, some with lugs, but no ring feet and sometimes decorated with short incised lines. Other forms found were shallow and flat bowls and a few bowls with slightly curved rims.

Decoration

Most sherds from the shell midden are plain black and burnished, and decoration consists of basket impression, circle stamping, applied bands, *pointillé*, and incised lines. Line incised pottery is most common in the lower spit (Spit 9) of the Shell Midden where as many as 23% of the sherds have line incised decoration (Hung 2008:185-192).

8.2.1.2. Lower silt layer

Ceramics

Approximately 64 kg of body sherds were recorded in the lower silt from pit 9 and pit 10, and 468 rims were analysed. There are three different categories of ceramic based on surface colour: red-slipped, buff and black. The dominant category is red-slipped (>60%) with fine sand temper (most probably natural tempered; see Chapter 9 on Analysis of Manufacture). The second biggest group is a thick, buff/beige, coarse sand tempered ware. Less than 0.1% of the whole assemblage is a black polished ware (Hung 2008:159-160).

Vessel forms

The most common vessels recorded in the Nagsabaran lower silts are two forms of bowl. One is a beige coloured simple bowl form with slightly curved rim and rounded lips, shallow body and round bottom. Their exterior surfaces sometimes carry basket or paddle marks (7% of the assemblage).

The second form is a red-slipped bowl with slightly curved rim and sometimes with ring feet and an inner projecting lip.

Two different forms of jars were also recorded from the lower silt layer:

a. Red-slipped vessels with everted and internally concave rims, sometimes with a carinated shoulder and a round base.

b. Jars with everted and internally straight rims, sometimes with carinated shoulders and round bases. The rims sometimes had an outer thickening of the lip or an inner projecting lip.

Other rim forms reported are a straight-sided vessel that only appeared in the upper Spits 10-13, and also a vessel that resembled a *dou*-vessel, a bowl with a wide lip and supporting ringfoot (see Figure 71; Hung 2008:162,163).

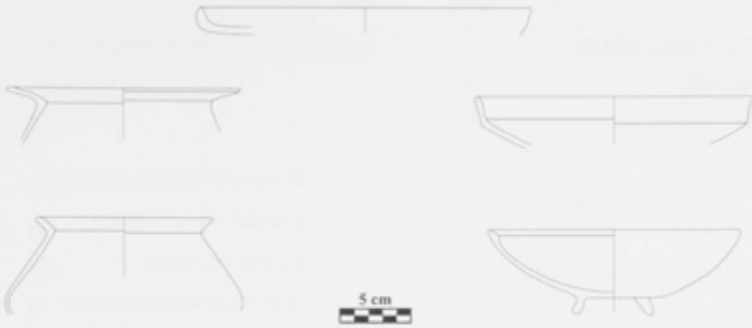


Figure 71. Different vessel forms from Lower silt at Nagsabaran (after Hung 2008:167-169).

Decoration

Five different décor elements were reported from sherds in the lower silt (see Figure 72 and Figure 73):

1. Paddle impressions were observed on the buff ware bowl, but also on some of the red-slipped ware.
2. Mat impression
3. Painted pottery (three sherds)
4. *Pointillé* or punctate stamping, forming rows of small round and pointed impressions, circle impressions and single line incisions. This décor was found on rims, the carinated shoulders and on ring feet, forming geometric patterns, straight or zig-zag lines. The punctations were not as rectangular as Lapita dentate punctate stamping, but lime infill was observed.
5. Fingernail impressions in rows around the vessel.

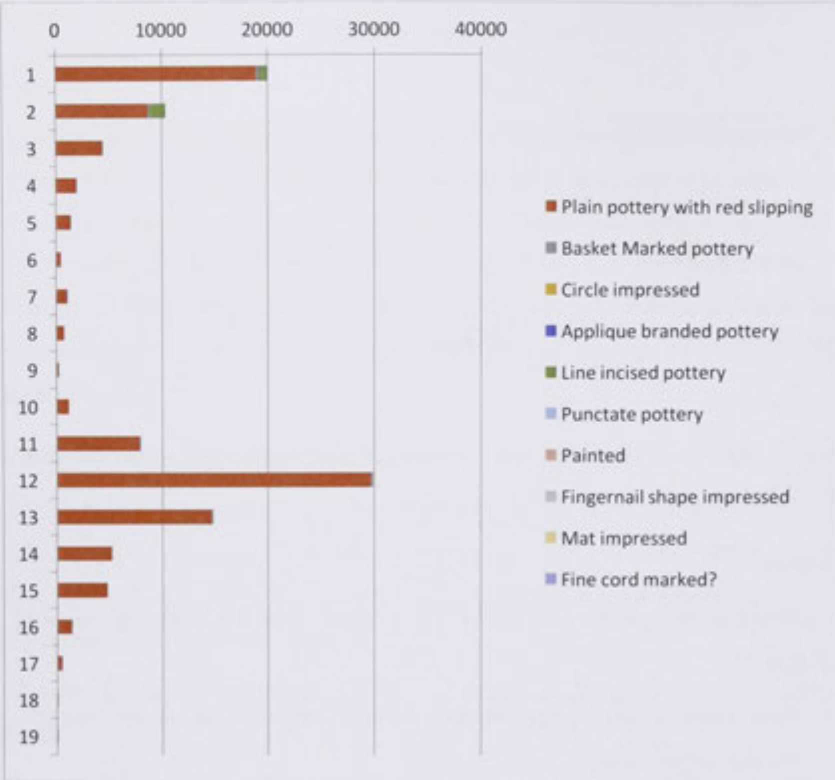


Figure 72. Pit 9. Percentage of decoration by weight (g) (modified after Hung 2008:347).

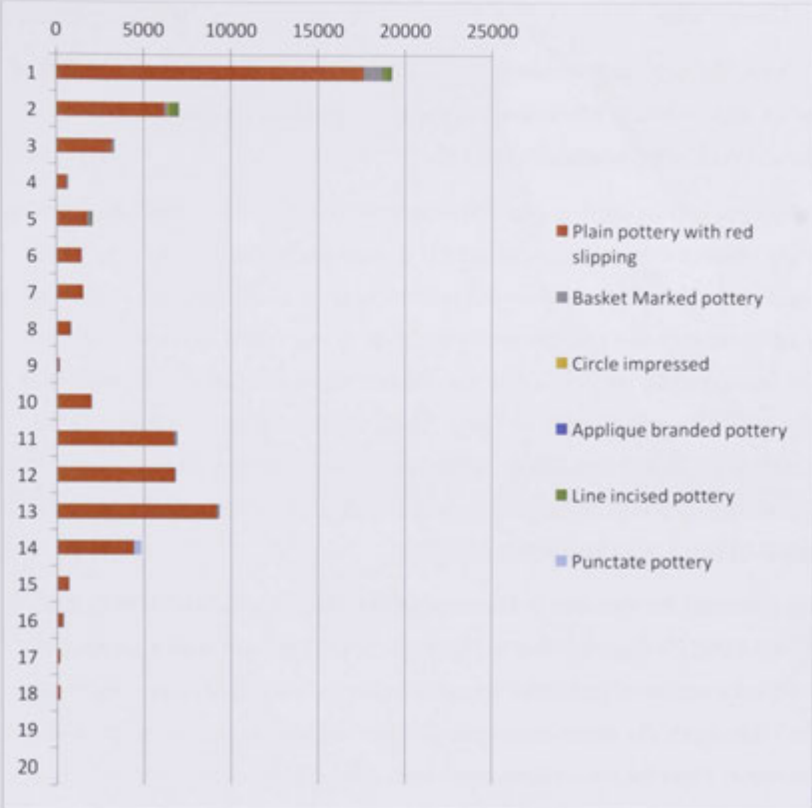


Figure 73. Pit 10. Percentage of decoration by weight (g) (modified after Hung 2008:347).

8.3. Ulong, Palau

Palau is located about 7 degrees north of the equator in the Western Caroline Islands of Micronesia, approximately 650 kilometres north of Papua and 900 kilometres east of Mindanao in the Philippines (see Figure 74).

The archipelago is comprised of over 300 islands, most of which are coralline in nature and locally referred to as the 'Rock Islands' (Fitzpatrick *et al.* 2003:1176). The Ulong (Aulong) Island group consists of several raised limestone islands situated 27 kilometres southwest of the main volcanic island of Babeldaob. Ulong Island is formed of eroded coralline limestone and has beaches on both the east and west coast. Prehistoric remains on Ulong Island are concentrated on a large beach flat on the northern island. In 1954 and in 1969, Douglas Osborne (1966, 1979) carried out extensive archaeological surveys, locating four sites on the island, and excavating on the main beach flat at an area called Aulong 1 Wall Test (Clark 2005:302).

Osborne excavated the four sites in later expeditions: AU1 (1966), AU2 (1967), AU3 (1968), and AU4 (1969), as detailed in Figure 74. In 1968 he excavated a 1.5 x 4.6 m trench behind a section of prehistoric limestone wall, and recovered pottery and midden down to 1.3 m depth. He observed that two different ceramic sequences existed within the excavation. From the lowest layer, rim sherds from simple bowls and everted jars with thin vessel walls were found, and from the above layers a thick-walled ceramic with a flange rim was recovered (Osborne 1979:76, Fig. 58).

In 2002-2003, Clark located the position of Osborne's 1969 Wall Test excavation, and a 1 m^2 test pit called TP.1 was excavated immediately east of it. Furthermore, in 2002, Clark excavated two 1 x 2 m units at each end of an 11 m transect. These were named unit 1 (eastern unit) and unit 3 (western unit; see Figure 74). The two units were excavated down to a depth of 220 cm (see Figure 75) below the surface (Clark 2005:354). The test excavations in 2002 suggested that an intact part of an early cultural deposit existed close to where the beach meets the raised Miocene-Pleistocene limestone slope. In 2003, two more 1 m^2 test pits (units 4 and 5) were excavated to sample the cultural deposit (Clark *et al.* 2006:218). Unit 4 was 3 m from the limestone slope and 8 m south of unit 5, and both were excavated down to a depth of 250 cm (Wright 2005).

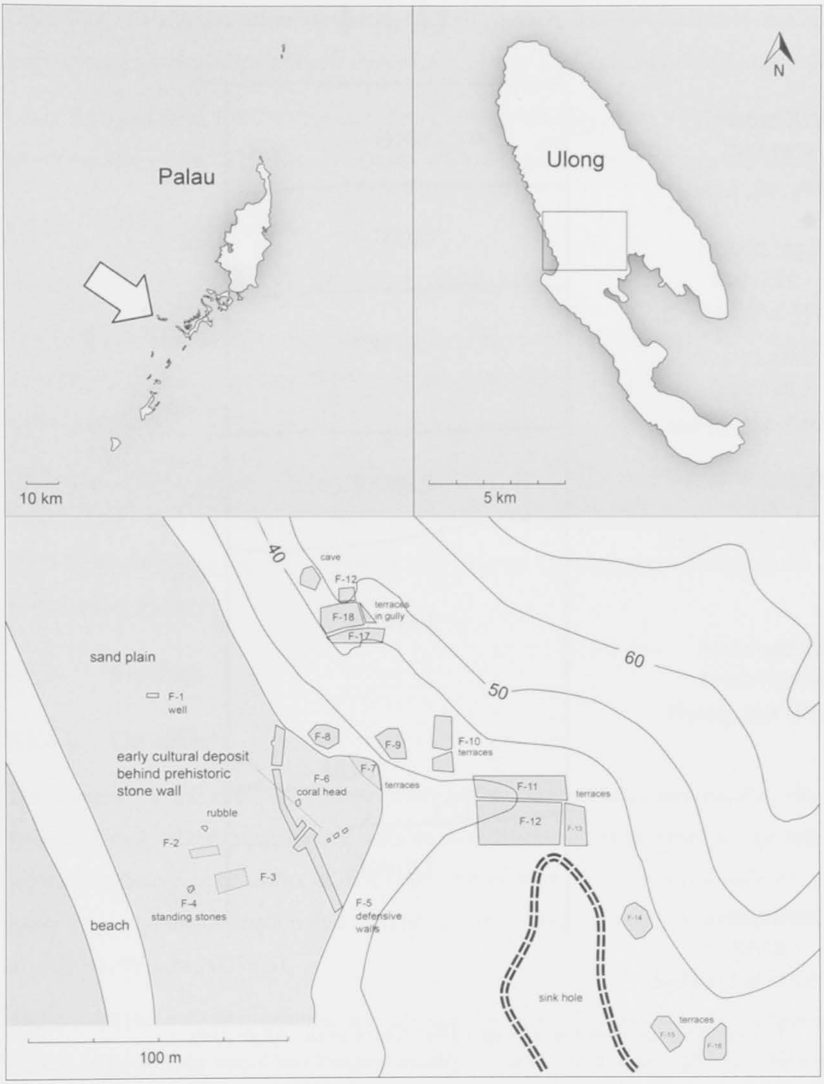


Figure 74. Map of Palau with Ulong and archaeological excavation. Courtesy of Geoff Clark

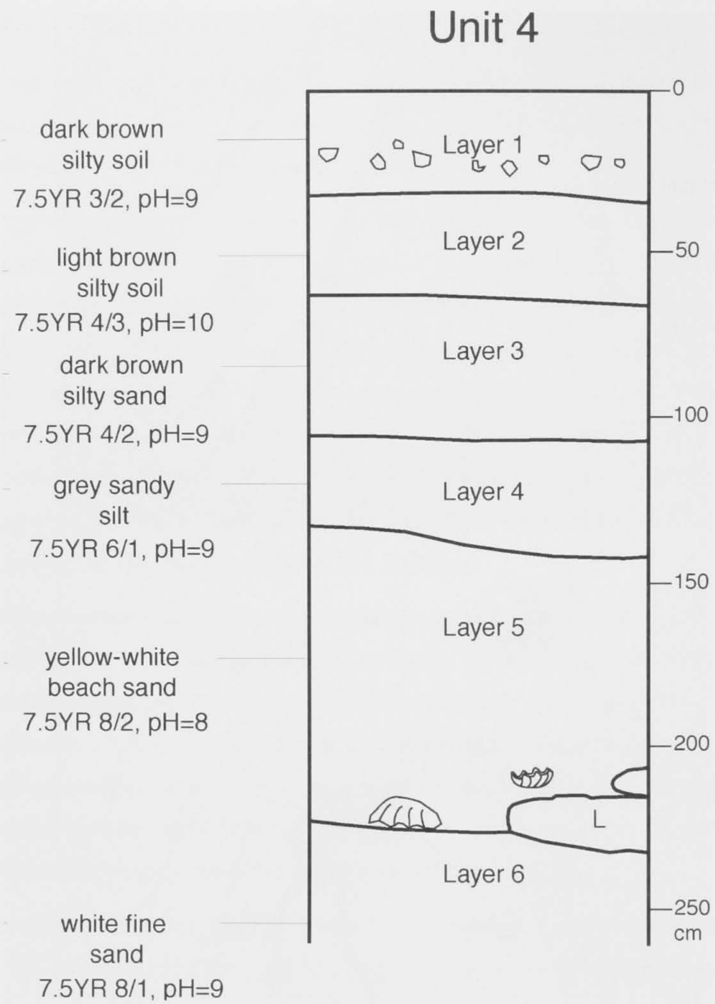


Figure 75. Stratigraphy of unit 4, Ulong (After Clark et al. 2006:219).

8.3.1. Stratigraphy

Test unit 4 was excavated down to 270 cm (Layer 6), where the three last spits 25-27 (30 cm) were culturally sterile.

Layers 1 and 2, from 0-60 cm consisted of large quantities of pottery, marine shell and bone down to 50 cm from late prehistoric village occupation.

Layer 3 at 60-110 cm showed some mixing between 95 and 100 cm. One complete ceramic vessel was found at the base of this layer.

Layer 4 at 110-130 cm below surface contained small numbers of bone and ceramics fragments, larger amounts of shell than earlier layers, charcoal and some burnt bone.

Layer 5 ranges from 130-240 cm with few finds of ceramics, bone or charcoal, but a larger amount of shell. This layer is considered to belong to the first settlement period.

8.3.2. Radiocarbon dates

Layer 5 is dated to 3150-2740 BP (Wright 2005:47-48).

The Ulong 2002 and 2003 excavations resulted in a total of thirty-one 14C dates which securely dated the site to 3100 BP to 500 BP (Clark 2005; Clark *et al.* 2006; Petchey and Clark 2010.

Clark *et al.* (2006) suggest that initial settlement took place somewhere around 3100-2900 cal BP. This age range has been confirmed by recent dating that suggests an age of 3000-2900 cal BP for the early deposits. See Chapter 10 for further discussion of radiocarbon dating.

8.3.3. Findings

8.3.3.1. Ceramics

The ceramics found at Ulong were probably not made from local clay sources, since limestone rock islands usually lack suitable clay deposits. The presence of volcanic crystals in the ceramics, either as deliberate or non-deliberate inclusions indicates a likely origin on the andesite based high islands Babeldaob and/or Koror (Fitzpatrick *et al.* 2003:2; Wright 2005:65).

There were three distinct ceramic assemblages found within the Ulong excavations (see Figure 76), and they could be stratigraphically divided into a basal style 120-240cm, a middle 60-120 cm and an upper assemblage 0-60 cm (Clark 2005:361; Wright 2005:94).

The basal ceramics, 120-240 cm

The vessel types deriving from the basal layers of Ulong consisted of medium-large sized globular to ovoid, moderately everted jars with a mean orifice diameter of 26-29.5 cm. A few rim sherds with vertical orientation indicate bowls were present. Decoration was very rarely recorded in this early assemblage, with only a few rims decorated with line incision (probably lime-infilled), fingernail impressions and one punctuate stamped with a single or multi-toothed tool. Red-slip was observed on some sherds although it was rare, probably because of erosion. The early ceramics were commonly tempered with volcanic sand and in some cases with a hybrid of beach sand (calcareous) and volcanic sand (Clark 2005; Wright 2005; see Chapter 9).

The middle ceramics, 60-120 cm

Rims sherds from 60-120 cm derive from a relatively thin-walled vessel with an everted rim, flat lip, and parallel rim profile. Some sherds show that the clay below the lip has been formed to create a small collar rim. Vessel types varied from a deep ovoid jar with vertical walls to a sub-globular jar with a short rim. The orifice diameter is smaller than the vessels found in the earlier layer, ranging from 23 cm to 27 cm with a few vessels with an orifice diameter less than 15 cm also recovered. Bowls with incurving walls and with slightly thicker rims and larger orifice diameters were also found in this layer. Except for one red painted sherd, no decoration was present at that phase. During that period, there was a change in temper, and from using volcanic sand and hybrid tempers, the Palauan potters started using grog temper (ground or baked clay) instead (Clark 2005; Wright 2005).

Upper ceramics, 0-60 cm

The main vessel form in the upper 40 cm at Ulong was a grog-tempered bowl with an inverted flange rim and a large orifice diameter of 31.5-36 cm. Some of the bowls were decorated with incised chevrons below the flanged-rim on a black (or sometimes orange-red) surface. From 40 cm down to 60 cm, a thick-walled bowl with a minor rim inversion and rims gradually thickening or thinning, was the dominant vessel type. The decoration from sherds from the last twenty centimetres of this phase is limited to two red painted sherds and a sherd with fingernail impression. The temper was exclusively grog or grog/volcanic sand.

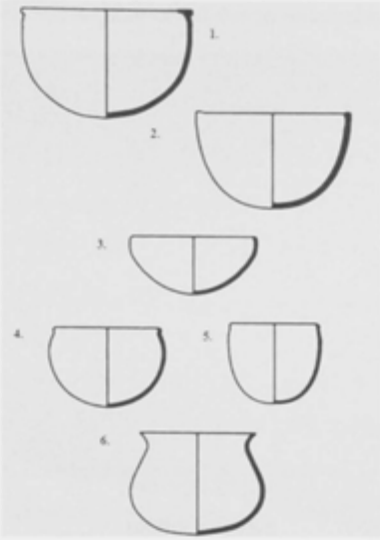


Figure 76. Different vessel forms from Ulong (Modified after Clark 2005:361). Vessel 1 and 2 belonging to the main vessel forms of Upper Ceramics 0-60 cm; Vessel 3-5 classified as Middle Ceramics 60-120 cm below surface; Vessel 6 belongs to Basal Ceramics 120-200 cm.

8.3.3.2. Non-ceramic artefacts

Lithic

Ten stone adzes have so far been recovered from the Ulong excavations: seven from TP1, unit 1 and unit 3, and three from unit 4. They were all made out of andesitic-basaltic volcanic breccia common on Babeldaob. Additionally, eight ironstone artefacts were recorded from TP1, unit 1 and unit 3. The ironstone artefacts are iron-rich and were probably used as a source of red pigment as they display groove marks.

Shell

The Ulong excavations produced very few shell artefacts. Only six were recovered and they were found between 30-160 cm, with four of these between 140-160 cm. The shell artefacts include two *Conus* sp. discs, a small bead of *Terebra* sp. and a *Terebra* shell adze, a drilled and ground piece of *Tridacna* sp. and a drilled pendant from either *Trochus* or *Conus* sp. (Clark 2005; Wright 2005).

8.4. Ambitle

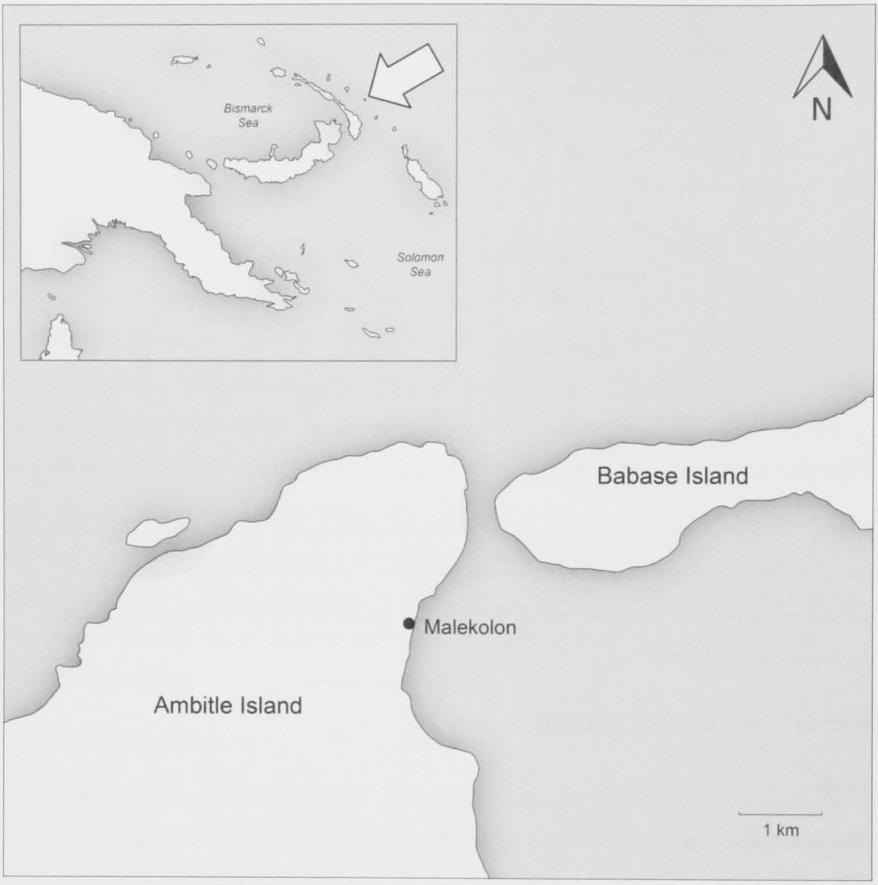


Figure 77. Map of Papua New Guinea and Anir Island group.

The Anir Island group consists of two islands, Ambitle and Babase (Figure 77). They are both volcanic islands with raised limestone at the eastern end of Babase. Ambitle is approximately 14 kilometres in length, with a maximum width of 10 kilometres. Lapita pottery was found by a local plantation owner who was digging drainage canals on the Malekolon plantation. The plantation owner, Mr. Graeme Carson, found 77 pottery sherds and some obsidian flakes that were analysed by White and Specht (1971). Ambrose excavated 19 m^2 at the Malekolon site (EAQ) in 1970 and 1971, but very little has been published on the excavation. Ambrose recovered several hundred sherds and ~90 % were plain. Out of the 10% decorated sherds, approximately 70% were dentate-stamped and 30% were incised. Together with the sherds, Ambrose also found obsidian, but no bone or wood due to poor preservation. The site was interpreted as disturbed by a flood event (Anson 1983:12).

The pottery from Malekolon was used by Anson (1983 and 1986) in his formulation of different types of Lapita assemblages, and was considered to be Far Western Lapita, now called Middle Lapita by Summerhayes (2000). Anson found 63 different types of motifs on the Ambitle sherds (Anson 1983:75).

The Malekolon (EAQ) site is located 500 meters inland in a small V-shaped valley bordered by cliffs to the north and south, and joining together on the western perimeter. The east of the site is bordered by the ocean and a reef-free beach (see Figure 78). In three field seasons of 1995, 1997 and 1998, Summerhayes re-excavated Malekolon to try to figure out the formation process at the site. Four test pits were excavated along an east-west transect from the beach inland. One test pit, TP4, was located 10 m from where Ambrose found pottery and described the stratigraphy in the 1970s (Figures 79 and 80.

Figure 78. Aerial photograph of Northern Ambitle with Ambrose site EAQ (courtesy of Wal Ambrose).

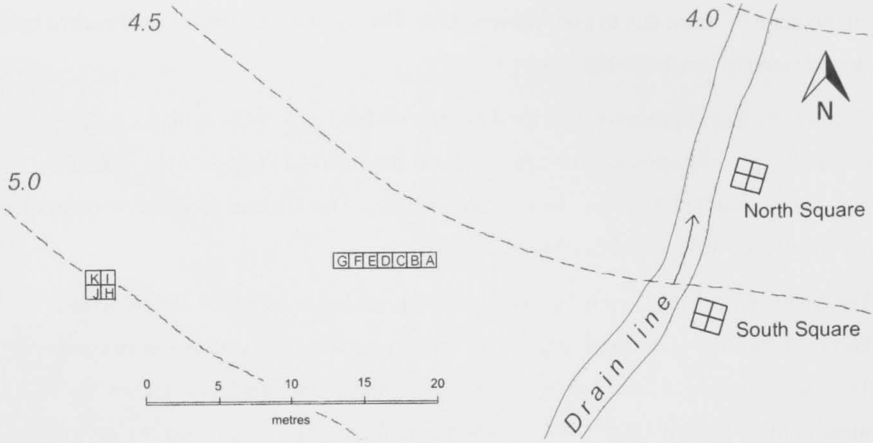


Figure 79. Map of Ambrose 1970's trenches (courtesy of Wal Ambrose).

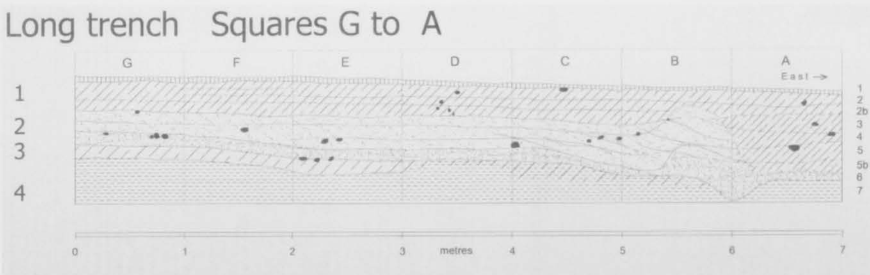


Figure 80. Stratigraphy of Ambrose's 1970's trench (courtesy of Wal Ambrose): 1) Clay soil topped by humus. 2) Fine volcanic ash and clay with pottery and obsidian. 3) Darker sandy ash with pottery and obsidian. 4) Dark mainly sterile volcanic ash deposit.

Analysis of TP4 showed that this pit was originally at the edge of an embayment 2300 years ago, when a volcano erupted on Ambitle and covered the island in ash that subsequently eroded into the valley and built up behind the reef. This build up acted as a dam, and clays from the top of the island eventually filled in the embayment (Summerhayes 2000:169).

The stratigraphy of TP4 showed a light brown ash sitting above a black beach sand layer of 25 cm overlaying a white beach sand (Summerhayes 2000).

The findings in Test pit 4 were numerous: 2559 sherds and 211 obsidian pieces, a stone adze, a possible stone chisel and a few pieces of quartz and chert were excavated. The decorated ceramics included dentate stamping, linear incision, shell impression and were of the same type previously reported by White and Specht (1971), and also found by Ambrose (personal communication July 2010). The sherds belong to bowls (6%), carinated jars (63%) and globular pots (25%), drawn in Figure 81. Analysis showed that 97 % of the pottery from Malekolon was made with a ferromagnesium fabric.

A proton-induced x-ray and proton-induced gamma-ray emission analyses (PIXE-PIGME) of obsidian found at EAQ (n. 89) showed that 36% of the obsidian derived from Willaumez Peninsula and 64% came from Admirality Islands (Summerhayes 2004: 148).

There are only three conventional radiocarbon determinations from the Malekolon excavations. The first date was from Ambrose's 1970s excavations and is on *Galip* nut with a span of: 2707 (1996) 1528 cal BP (ANU 957). The other two dates derive from Summerhayes' excavations and are on charcoal: 3830 (3430) 2960 cal BP (ANU 11193) and 2750 (2080) 1530 cal BP. All three determinations have large age ranges of some 900 years (Summerhayes 2000:173).

Figure 81. Reconstructed vessels from Ambitle.

9. Manufacturing study

A ceramic manufacturing study was made to examine how raw materials were chosen and used by prehistoric potters in the Mariana Islands. Ceramics from four other Neolithic sites were examined and compared to identify similarities and differences among different Neolithic pottery-producing communities in the Indo-Pacific.

Archaeological study of pottery has tended to focus on either style or function, where *style* has often been defined as cultural embellishment, and viewed in terms of symbolic communication. In contrast, the technology involved in making pottery has most often been viewed in functionalistic terms where the potter is solving a problem related to the efficiency of the container (Larsson and Graner 2010:219).

By examining the choice of raw material and manufacturing techniques, it is possible to try and distinguish between two 'sets' of variation in a ceramic assemblage: those resulting from material source differences, and those that reflect the traditional production techniques of a pottery culture.

Potters have been shown in many ethno-archaeological studies to be highly conservative in their nature and choice of material (i.e. clay and temper). This appears to be universal among contemporary potting groups, although the material preferences are not: one community may use coarse clay while another uses fine clay, and temper choice is similarly diverse but often group-specific (Gosselain 1994; Sillar 1997; Larsson and Graner 2010). Studies undertaken among potters in modern traditional societies have shown that potters are reluctant to change their method of manufacture even though they admit that another group's pottery has a better reputation or that their manufacturing methods are more efficient. The practise of potters is intimately linked to social identity and family traditions. The manufacturing of pottery is almost always taught by a close relative, a parent or a grandparent, and is therefore a part of the cultural inheritance. The shaping of the vessel has been postulated to be a particularly conservative activity and is strongly associated with tradition and cultural identity (Smith 1989; 1999?; Larsson and Graner 2010). The practise of potting is taught from a very young age and the local *chaîne opératoire,* or operational sequence, is integrated in part at a sub-conscious level. This results in the potter not thinking of production in terms of technical choice, it is simply the culturally proscribed "way to make pottery" (Barley 1994:115; Gosselain and Livingstone Smith 2005:41). When the potter is confronted with different, and perhaps better, alternative technology choices, most will reject them as valid, yet foreign and not only requiring extensive learning to reproduce but culturally inappropriate. Pottery change occurs over time, but the pace and extent depends on cultural attitudes towards innovation and very rarely happens instantaneously. When there is substantial change in material, vessel shape and technology of pottery there is almost always, in modern situations, pressure exerted from a market economy and commercialisation of production. Potters in small-scale traditional societies tend to be very conservative and not change their craft since it is deeply embedded in their identity and acts as a link to the past (Larsson and Graner 2010:226).

With this background in mind the manufacturing study of the Unai Bapot ceramics and other assemblages was carried out in four steps.

9.1. Methods

First, all sherds were photographed and drawn and when the size of the sherd allowed it, rim diameter and vessel shape was estimated. Unfortunately, a large portion of the original data was stolen in 2013, including the photographs and reconstruction of sherds, before the manufacturing analysis was carried out. Therefore, several photographs in this study are of cut sherds, before the second analysis of the same sherds was completed (See Appendix1:120-243).

Second, all rim sherds were cut with a gem saw and the surfaces of the sectioned rim sherds were polished. The polished surface was then impregnated with araldite plastic mixed with a fluorescence agent, and examined under a stereo microscope with the aid of a UV light (see Figure 48 in Section 7.6.5). While forming the ceramic with plastic clay, the potters apply pressure on the clay particles. This pressure causes the elements in the clay to acquire a perpendicular orientation to the direction of the forces applied on them (Santacreu 2014). By examining the orientation of the pores, it is possible to determine whether a pot was formed by coiling, pulling or 'paddle and anvil' technique (see Figure 82). Using the polishing method, even very thin pores resulting from a particular manufacturing technique can be observed (Lindahl and Pikirayi 2010; Winter *et al.* 2012).

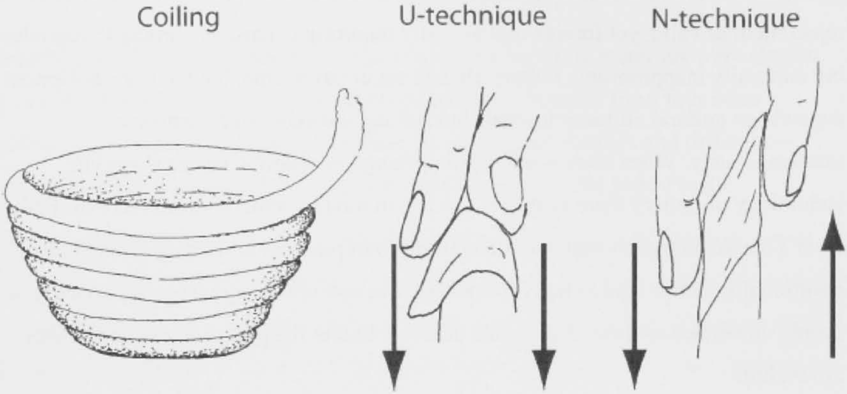


Figure 82. Forming a vessel using N and U-coiling techniques (after Lindahl 2010:139).

Third, sherds from each assemblage were made into thin sections in order to study the grain size distribution and the composition of larger grains, in order to discern added temper. By doing this, the mineralogy and coarseness of the original clay could be analysed separately, as it can supply important information about the raw material. At this stage, there was a problem as several of the glass microscope slides on which the sherds were mounted, were broken due to a fabrication problem with the glass backing. Due to the large amount of time necessary to prepare new thin sections, the number of ceramic measurements varies between assemblages, and is lower than the optimal number of measurements initially planned. All sherds submitted by different excavators from every site, were drawn, and when possible vessel reconstructions were carried out (see each site in Appendix 1). Measurements and calculations were made on the coarse grain fraction of each cut sherd with the aid of image analysing equipment consisting of a three-chip colour video camera mounted on a microscope, connected to a frame grabber in a computer. The KONTRON KS 300 software was used for image processing and analysis.

Fourth, a thermal colour test (refiring) was conducted to test the suitability of raw clay for ceramic production and to determine the original firing temperature (see Appendix 1:120; 158; 189; 212; 243). The test uses the successive changes in colour of the ceramic material induced by gradual heating. The refiring is done in a laboratory furnace with an oxidising atmosphere in stages of 100°C up to 1000°C and the difference in colour in the ware is registered according to the Munsell soil colour chart. The colour changes in a range between the original firing temperature and the beginning of the sintering phase at ~1000°C because of iron oxides, calcium and other colour agents in the clay. The different phases of darkening, glazing and melting are determined by the minerals in the raw clay. From 1000°C the samples are reheated in 50°C intervals until they melt/vitrify (Lindahl personal communication 2012).

9.2. Sample selection

9.2.1. Bapot, Saipan

From Unai Bapot, 23 sherds were sampled, sectioned and impregnated with araldite plastic mixed with a fluorescence agent. Of these, all 23 sherds were thin sectioned and studied, with measurements and calculations carried out on the coarse fraction present in nine sherds. Another five sherds were studied with the thermal colour test.

9.2.2. Chaolaiqiao, Taiwan

Twelve sherds from The Chaolaiqiao site on the south east coast of Taiwan, supplied by H-C. Hung were selected from levels dating to 4000 BP. Sherds were then thin sectioned and studied as described above, with measurements and calculations carried out on the coarse fraction present in all twelve sherds. Five sherds were studied with the thermal colour test.

9.2.3. Nagsabaran, Philippines

Thirteen sherds from the Nagsabaran site in northern Luzon, Philippines, were supplied by H-C. Hung selected from levels dating to ~4000-3300 BP. Measurements and calculations were carried out on the coarse fraction present in eight sherds. Five sherds were studied in a thermal colour test.

9.2.4. Ulong, Palau

Twelve sherds from the Ulong site in Palau supplied by G. Clark, dated to ~3100-2800 BP, were examined. Measurements and calculations were carried out on the coarse fractions of ten sherds. Five sherds were studied in a thermal colour test.

9.2.5. Malekolon, Ambitle Island, the Bismarck Archipelago

Eight sherds from the Malekolon Plantation site, Ambitle Island, supplied by W. Ambrose, dated to Middle Lapita period (2900- 2700 BP), were examined. Measurements and calculations were carried out on the coarse fractions of eight sherds. Five sherds were studied in a thermal colour test.

9.3. Analysis and results

9.3.1. Bapot

Twenty-three rim sherds from Block A, Unai Bapot, were chosen for the manufacturing analysis as they derive from the whole sequence at Unai Bapot with, emphasis on the earliest Early Pre-Latte Period layers (16 sherds from 260-160 cmbd and seven sherds from 160-23 cmbd). The sherds represent a variety of vessels: jars with outcurving rim with rounded or converging lips (O1, O2 and O3, see Chapter 7.6), thin ware bowls (B1), carinated vessels, and from earlier layers, bowl and pans (B1, D1 and D2). Of the of 23 sherds, 12 were thin sectioned. Petrographic study showed that all the sherds had an added temper of calcareous sand, but BAT 20 (190-200 cmbd), BAT 22 (180-190 cmbd), and BAT 25 (150-160 cmbd), also contain mixed sand and volcanic sand (See Appendix 1:103). The fraction of coarse grains in Bapot sherds (>0.02 mm) varied from 19-35%. Grain size varies between 0.02 to 0.50 mm. The majority of the sherds (18 out of 23) have pores running parallel to the vessel surfaces and pore orientation indicates they were formed by use of the paddle and anvil technique. Eight of the 18 sherds have pores that indicate that the potter added a coil at the very top of the rim (see Appendix 1:73). Three sherds were formed using coiling technique; BAT 33, BAT 34 and BAT 36 (See Appendix 1: 98-101). These sherds derive from younger layers 130-23 cmbd that were dated ~2310-1280 cal BP.

Thermal tests indicate that most Bapot ceramics were fired at relatively low heat (600-700 degrees Celsius) with some perhaps as high as 800 degrees Celsius (see Appendix

1:Table 25). The core of the pottery was a dark grey to black and only the outermost part, often less than 0.1 mm thick, was oxidised red. This might be due to firing under reduced conditions, which prevents de-carbonation of the calcium carbonate which is common in an oxidised atmosphere (Lindahl *et al.* 2006; Winter *et al.* 2012), and then only at the end of the firing were the vessels exposed to an oxidised atmosphere. Another possible reason for this might be to control the colour of the vessels, as an abundance of oxygen when firing gives a lighter colour to the finished ceramic vessel. The firing time was probably around 45 minutes to one hour (Winter *et al.* 2012:906; Lindahl and Matenga 1995).

9.3.2. Chaolaiqiao, Taiwan

The 12 sherds from the Chaolaiqiao site, pit 1, are all rims sherds belonging to red-slipped vessels/jars with an inner projecting lip and restricted concave rims. One rim sherd probably derives from a plate or shallow bowl (type TAN 15) (see

Table 12). Orifice diameters range from 17-24 cm. The 12 sherds analysed from Chaolaiqiao were all made of a silty or fine sandy clay with no added temper. Some inclusions of pyroxene and plagioclase were observed, but these probably belong to the clay from the Coastal Range of Taiwan, a remnant of a westward-facing Neogene island arc, rather than being an added temper. The fraction of coarse grains (>0.02 mm) was 12-26 % and the majority of grains (85-94%) were in the silt fraction (<0.06 mm). The Chaolaiqiao ware is very dense and this complicates the identification of pore orientation lines. The majority of sherds (10 out of 12) have pores running parallel to the vessel surfaces, indicating they were formed by a paddle and anvil technique (see Appendix1: 131- 158 &

Table 12). The exceptions are sherds: TAN 5 and TAN 17 (see Appendix1:136; 1: 152) where the pore orientation is diagonally oriented in thin section, suggesting that these two sherds were formed using the N-coiling technique. Thermal tests indicate that the Chaolaiqiao ceramics were able to withstand temperatures well over 1000 degrees Celsius. The vessels were fired in an oxidising atmosphere, probably an open fire, to a temperature of 900-1000 degrees Celsius. The fabric was fired completely throughout, indicating complete oxidation with the duration of firing about an hour or more (see Appendix 1:158).

9.3.3. Nagsabaran, Philippines

Thirteen rim sherds from Nagsabaran, Squares P9 and P10 were analysed. The Nagsabaran reconstructed vessel forms (see Figure 71, Chapter 8.2.1) included restricted jars with a sharp everted rim-body corner point, bowls with ring feet, incurved lips and flat-based platters/trays with a red-slip or beige colour. Of the 16 rim sherds, eight were thin sectioned and all were composed of fine sandy clay with no added temper. The fraction of coarse grains (>0.02 mm) was 8-14% (see Appendix 1:187), and the majority of grains (60-70%) were in the silt fraction (<0.06 mm) with the exception of NAG 5 where 85-98% of grains were fine sand see Appendix 1:168) . The majority of the sherds (10 out of 13) were formed using the N- and U-coiling techniques because the pore orientation is diagonally orientated and in some cases is even ∩-shaped (see Figure 82). Thermal tests indicate that the Nagsabaran ceramics were able to withstand temperatures well over 1000 degrees Celsius. The vessels were fired in an oxidising atmosphere, probably an open fire, to a temperature of 700-800 degrees Celsius (see Appendix 1:189). The greyish core of the fabric indicates incomplete oxidation, and the duration of firing was probably not more than an hour. Two of the 13 sherds (NAG 14; NAG 16) that were selected by Hung for this study derive from Spit 2 of pit 10 (shell midden) which is dated to 2000-1500 cal BP (Hung 2008:158).

9.3.4. Ambitle, Bismarck Archipelago

Twenty-five sherds from the Malekolon Plantation site, Ambitle Island, were analysed. The Ambitle reconstructed vessel forms (see Figure 81, Chapter 8.4) include restricted jars with round everted rims, jars with everted rims with thickened lips, and unrestricted bowls. Of the 25 sherds, 10 were thin sectioned (two samples broke and could not be analysed). Ambitle sherds have added temper consisting of a mix of minerals and coral sand that were divided into dark and light grains. The fraction of coarse grains (>0.01 mm) was 12-37 % (see Appendix 1:210) and the grain size ranges between 0.01-0.2 mm, indicating a moderately sorted temper of subrounded aggregates of beach origin mixed with volcanic material. All sherds analysed (n=8), except for AME11, have pores that run parallel to the vessel surfaces, with pore orientations indicating they were formed by a paddle and anvil technique. AME 11 has diagonally orientated pores at the lip of the sherd, which is probably the result of the potter adding a coil at the very top of the vessel to shape the rim. This approach to rim building was observed in the Unai Bapot assemblage, and has been identified in the Ulong assemblage: it appears to be a common method of forming a vessel orifice in the Indo-Pacific. Thermal tests indicate that the Ambitle ceramics were able to withstand temperatures well over 1000 degrees Celsius. The vessels were fired in an oxidising atmosphere, probably an open fire, to a temperature of 800-900 degrees Celsius, (see Appendix 1:212) but one sample appears to have been fired at a temperature up to 1000 degrees Celsius, which could indicate a reduced firing environment at the end of the firing process.

9.3.5. Ulong, Palau

Ten sherds from Ulong were analysed. Several of the Ulong sherds were eroded from inter-tidal exposure and broke easily while preparing thin sections. The Ulong reconstructed vessels forms are all moderately everted jars, with some minor differences in rim angle (see Figure 76, Chapter 8.3.3). The Ulong sherds have added temper consisting of a mix of mineral, volcanic, and calcareous sand. The fraction of coarse grains (>0.01 mm) was 13-34% (see Appendix 1:241) and the grain size ranges between 0.01-0.45 mm and was poorly sorted. The poor sorting could be a result of terrigenous grains having been embedded in the clay used for pottery making. All sherds have the pores running parallel to the vessel surface, indicating that they were formed by the paddle and anvil technique. Thermal tests indicate that the Ulong ceramics were fired at a relatively low heat of 600-700 degrees Celsius (see Appendix 1:243). The vessels were fired in an oxidising atmosphere, probably an open fire. Three sherds have a greyish core, indicating incomplete oxidation, perhaps due to firing under reduced conditions, which prevents de-carbonation of the calcium carbonate. Clays in Palau used in recent times have a high organic content which can affect core colour, as carbon from organics is not completely driven out (Geoffrey Clark, personal communication, 2015). The duration of firing was probably not more than an hour.

Table 12. Different manufacturing techniques. Note that Nagsabaran has a high incidence of coiling relative to other assemblages. BAT = Unai Bapot, Saipan; NAG = Nagsabaran, Luzon; TAN = Chaolaiqiao; AME = Ambitle, Anir; ULG = Ulong, Palau. (BAT 119 and 17 is paddle and anvil with the end of the rim finished by a coil)

BAPOT

Lab. no.	Cat. no.	Pore line analysis result
BAT 1	176:8	Paddle and anvil
BAT 3	172:21	Paddle and anvil
BAT 4	170:1	Paddle and anvil
BAT 6	170:2	Paddle and anvil
BAT 10	160:3	Paddle and anvil
BAT 11	159:3	Paddle and anvil
BAT 14	159:1	Paddle and anvil
BAT 16	145:2	Paddle and anvil
BAT 17	143:1	Paddle and anvil
BAT 20	129:2	Paddle and anvil
BAT 22	125:4	Paddle and anvil
BAT 25	100:8	N/A
BAT 27	153:3	Paddle and anvil
BAT 28	137:5	Paddle and anvil
BAT 29	119:2	Coiling/Paddle and anvil
BAT 30	117:3	Paddle and anvil
BAT 31	100:12	Paddle and anvil
BAT 32	91:2	Paddle and anvil
BAT 33	76:5	Coiling
BAT 34	62:1	Inconclusive
BAT 35	42:2	Inconclusive
BAT 36	3:1	Coiling

COMPARATIVE MATERIAL

Lab. no.	Pore line analysis result
TAN 1	Paddle and anvil
TAN 2	Paddle and anvil
TAN 4	N/A
TAN 5	Coiling
TAN 7	Paddle and anvil
TAN 9	N/A
TAN 10	N/A
TAN11	Paddle and anvil
TAN 12	Paddle and anvil
TAN 13	Paddle and anvil
TAN 14	Paddle and anvil
TAN 15	Paddle and anvil
TAN 16	Paddle and anvil
TAN 17	Coiling/Paddle and anvil (?)
TAN 19	Paddle and anvil

Lab. no.	Pore line analysis result
NAG 1	Paddle and anvil
NAG 2	Coiling
NAG 3	Coiling
NAG 4	Coiling
NAG 5	Coiling
NAG 6	Coiling
NAG 7	Coiling
NAG 8	Coiling
NAG 11	Coiling
NAG 12	Coiling
NAG 16	Coiling
NAG 17	N/A
NAG 18	N/A

Lab. no.	Pore line analysis result
AME 1	Paddle and anvil
AME 2	Paddle and anvil (?)
AME 11	Paddle and anvil
AME 15	Paddle and anvil
AME 20	Paddle and anvil
AME 23	Paddle and anvil
AME 25	Paddle and anvil
AME 26	Paddle and anvil

Lab. no.	Pore line analysis result
ULG 1	Paddle and anvil
ULG 2	Paddle and anvil
ULG 3	Paddle and anvil
ULG 5	Paddle and anvil
ULG 6	N/A
ULG 7	Paddle and anvil
ULG 8	Paddle and anvil
ULG 11	Paddle and anvil
ULG 12	Paddle and anvil
ULG 14	Paddle and anvil

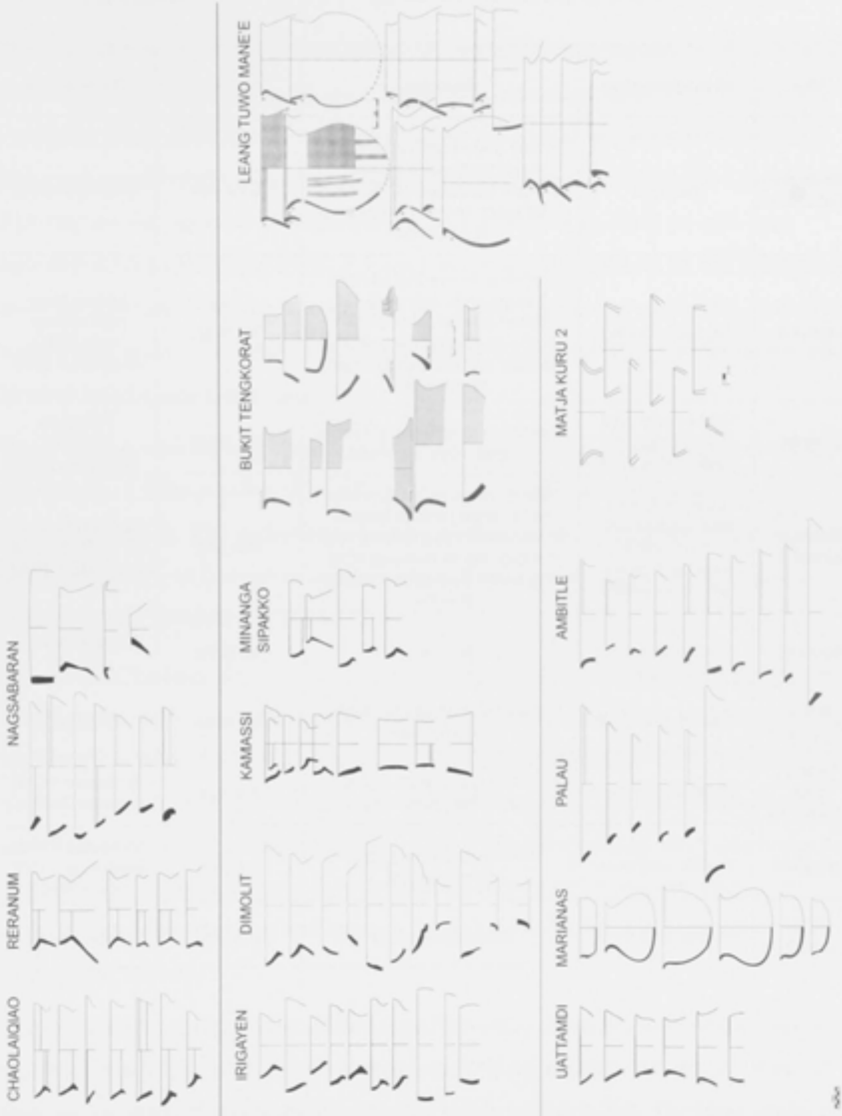


Figure 83. Different vessels from ISEA and the Pacific. Chaolaiqiao and Nagsabaran after Hung 2008; Reranum, Batanes, Irigayen and Dimolit after Swete Kelly 2008; Kamassi and Minanga Sipakko after Anggraeni et al. 2014; Bukit Tengkorak after Chia 2003; Leang Tuwo Mane'e after Bellwood 1976; Uattamdi after Irwin et al. 1999.

Table 13. Description of manufacturing and temper.

Site	Manufacturing	Temper	Thickness	References
Reranum, Batanes	No data	Poorly sorted and subangular volcanic sand, dominant mineral grains are plagioclase feldspar and green-brown hornblende	5-10 mm	Dickinson 2008
Irigayen	Probably coiling	Poorly to moderately sorted fluvial sands composed of subangular to subrounded grains of dominantly volcanic detritus. plagioclase feldspar, hornblende	No data	Swete Kelly pers. comm. July 2015; Dickinson 2008
Dimolit	Coil or ring built and finished by paddle and anvil	Stream-derived sand and rare volcanic rock fragments	No data	Peterson 1974:33; Dickinson 2008
Minanga Sipakko	Low fired, slab built, paddle and anvil with a majority finished with slow wheel	Black minerals, mica, white sand, large reddish lateritic inclusions (probably local river sands). Some rare sea shell fragments, pyrites and maybe obsidian	No data	Anggraeni *et al.* 2014; Bulbeck & Nasruddin 2002
Kamassi	Only reconstructed vessels	No data	No Data	Anggraeni *et al.* 2014
Bukit Tengkorak	Paddle and anvil	Volcanic minerals, volcanic rock fragments	No data	Chia 2003
Leang Tuwo Mane'e	Paddle and anvil	Very fine grain white material, possible coral sand	2-8 mm	Bellwood 1976; Daud 2001
Uattamdi	Paddle and anvil	Calcareous (coral) and volcanic sand	3-4 mm	Bellwood 1992; Irwin *et al.* 1999; Kirch 1997
Matja Kuru2	Paddle and anvil	Calcareous sand	2-5 mm	Winter in prep.

9.4. Discussion

The manufacturing study has recorded significant differences among the five ceramic assemblages and also among the nine additional assemblages from ISEA (Table 13; except for Matja Kuru2, none were analysed by the author, and several assemblages lack vital manufacturing data, but existing data and reconstructed vessels are presented). Not only are the ceramics very different at macroscopic scale, they are also very different at the microscopic scale. Although some similarities do exist, the similarities are fewer than the differences, when considering the region as a whole. All assemblages contain red-slipped sherds from bowls and jars, with everted rims, and the paddle and anvil technique was widely used.

However, the ceramic similarities are rather generic and the manufacturing study shows that potters at different sites all had their own *savoir faire* and followed their own *chaîne opératoire*. The in-depth production study does show that there might be some assemblages that have more in common than others, and that there might be shared ceramic trends in particular areas.

The most technologically advanced ceramics, regarding the choice of raw material (a clay that did not require temper and could withstand very high firing temperatures), are the ceramics from Chaolaiqiao. The selection of the clay could be fortuitous, and reflect geological factors rather than deliberate choice, but considering that Taiwan has an early history of ceramic manufacturing ~6000-5500 cal BP (Hung 2008:24), it seems plausible that the long history of pottery manufacturing in Taiwan has led to technological developments and innovations that are reflected in the quality of the Chaolaiqiao pottery.

The ceramics from Nagsabaran (Luzon) and Reranum (Batanes) have some similarity with the Chaolaiqiao assemblage as proposed by Hung (2008), with vessels from all sites having sharp everted concave rims and bowls with ring feet. The same vessel types are present at Irigayen and Dimolit as well. While both Chaolaiqiao and Nagsabaran assemblages were made with a silty or very fine sandy clay with no added temper, Reranum sherds are tempered with volcanic sand. The ceramics from Nagsabaran are also able to withstand very high temperatures and were fired at relatively high temperature, but in contrast to the sherds from Chaolaiqiao they are not fired all way through, indicating incomplete oxidation and a shorter firing time. The other two northern Luzon sites, Irigayen and Dimolit, both have added tempers. Irigayen is tempered with volcanic sand while Dimolit is tempered with stream sand. The major difference between Chaolaiqiao and the sites in northern Luzon is that the majority of the Chaolaiqiao sherds were formed by paddle and anvil (two sherds might have been manufactured by coiling technique), while at Nagsabaran the majority of vessels examined were formed with the coiling technique. This is also the case with Dimolit ceramics and most likely with Irigayen (Swete Kelly personal communication, 2015), and could perhaps indicate coiling was a northern Luzon ceramic tradition, although too little data is available at present. This is interesting since it has been argued that Chaolaiqiao and the Cagayan Valley sites, Nagsabaran especially, are closely related from a ceramic perspective (Hung 2008). Northern Luzon is the only area within this study where ceramics are manufactured using the coiling method. The rest of the analysed assemblages and the additional ISEA sites (Leang Tuwo Mane'e rock shelter in Talaud; Minanga Sipakko and Kamassi, in Karama Valley, Sulawesi; Bukit Tengorak, Borneo; Uattamdi, Kayo Island, Moluccas; and Matja Kuru 2, East Timor) are all reported as being manufactured by paddle and anvil (there are no data for Kamassi except reconstructed vessels, but the site is reported to be closely linked to Minanga Sipakko ceramic trends). The Karama Valley assemblages show closer affinity with ceramics from Taiwan, Batanes and northern Luzon than with sites further to the east and to Bukit Tengkorak in the west, regarding vessel forms and temper.

Early Karama Valley vessels are red-slipped and have tall and/or concave rims and some pots of pedestal stand type. Some of the early ceramic sherds are incised or have stamped décor. The similarities between Karama Valley and sites to the north have been pointed out by the excavators (Anggraeni *et al.* 2014: 750), but unfortunately Anggraeni *et al.* present very little data on a microscopic level to allow a comprehensive comparison. More detailed information on ceramics excavated at Minanga Sipakko is supported by Bulbeck and Nasruddin (2002), who report that the pottery is low fired, slab built and/or paddle and anvil, with a majority of the vessels finished with the slow wheel. To my knowledge, the slow wheel is not reported from any other early Neolithic sites in ISEA (the term is fairly meaningless since potters are capable of tuning the pot in their hands to achieve almost perfect spherical/round form) but some sort of spinning or turning is suggested by a very few, rare sherds from the Mariana Islands (Carson 2014:56). Added temper in Minanga Sipakko sherds consist of: black minerals, mica, white sand, large reddish lateritic inclusions (probably local river sands), some rare sea shell fragments, pyrites and perhaps obsidian.

The Karama Valley ceramics are said to have generic similarities with Eastern Sabah, but differ largely in vessel forms, for example, with Bukit Tengkorak (Figure 83). Concave and tall rims are not reported from early deposits at Bukit Tengkorak and Anggraeni *et al.* (2014) suggest that the Karama sites and Bukit Tengkorak might have both had connections in early times with the Philippines, but were never in direct contact with each other. Several of the Bukit Tengkorak vessels show closer affinity with vessel types from sites such as Leang Tuwo Mane'e (Talaud Islands), Uattamdi (Moluccas), Ulong (Palau), Unai Bapot (Mariana Islands) and with vessels recorded at various Lapita sites including Ambitle (Anir Island), where the vessels have out-curved rounded rims rather than sharp, everted, tall, concave rims (vessels with sharp everted rims are reported at Lapita sites). One significant difference between Bukit Tengkorak and the above-mentioned assemblages is that several different vessel stands have been reported from Bukit Tengkorak, but no such stands are reported from the other sites except from early Lapita sites, where they are relatively common

The Bukit Tengkorak vessels are manufactured by paddle and anvil, and tempered with volcanic sand, sometimes with volcanic rock fragment (Chia 2003).

The early Leang Tuwo Mane'e red-slipped ceramic assemblage shows a large variety of different vessel forms where the majority are globular vessels with rounded, out-curved rims. The vessels are made by paddle and anvil, and are a thin ware with a body-sherd thickness of 2-8 mm, tempered with calcareous and volcanic sand. The Leang Tuwo Mane'e assemblage has its closest parallels to contemporary ceramic inventories at Bukit Tengorak and Uattamdi (Irwin *et al.* 1999:372).

The pottery from Uattamdi consists of few vessel types, where the main characteristics are restricted pots with everted rims and bowls with direct rims. The body-sherds are very thin, with a thickness of 3-4 mm, manufactured by paddle and anvil, and tempered with calcareous and volcanic sand. Uattamdi has been closely linked to Lapita and Patrick Kirch describes them as virtually identical in vessel form to that from Lapita sites like Talepakemalai and Etakosarai in Mussau (Kirch 1997:50). Uattamdi vessels also have a close affinity with vessels from the earliest assemblages from the Mariana Islands (Figures 50 and 83) and to vessel type 6 at Ulong (see Figure 76).

Very similar vessels to Uattamdi, early Ulong and Early Pre-Latte vessels from the Marianas, are recently documented by the author (October 2015) from Neolithic layers at the early Pleistocene site Matja Kuru 2, East Timor. A first analysis shows that very thin 2-5 mm red-slipped vessels with everted rims, and some bowls with direct rims, were tempered with calcareous sand and manufactured by paddle and anvil.

Early red-slipped pottery tempered with calcareous and volcanic sand is also reported at Site PA 1, Pulau Ay, Banda Islands, dated to 3500-3400 cal BP (Peter Lape, personal communication,. 2014) but no report on vessel type or manufacturing is available at present.

Ceramics from Ulong in Palau show a small variety of different vessel forms and all sherds derive from everted jars with some minor differences in rim angle. The potters added 13-34% temper consisting of a poorly sorted mix of mineral, volcanic, and calcareous sand to the clay. In the case of early ceramics from Ulong, the temper might reflect geological factors rather than the optimal choice of raw material. There are no good clay deposits on Ulong, as it is a limestone rock island and pottery is known to have come from andesite islands such as Babeldaob and Koror (Fitzpatrick *et al.* 2003:2). The volcanic sand in the Ulong sherds might have been incorporated in the clay naturally, rather than being added as a deliberate temper (Dickinson 2006:46). There is also a possibility that it was not the pots that were imported to Ulong, but the clay. When the clay arrived at Ulong the potter needed to add more temper and this could explain the hybrid temper that was in the Ulong sherds. The Ulong sherds are relatively low-fired at a temperature of 600-700 degrees Celsius, which might be necessary if the clay is tempered with calcareous sand.

The ceramic assemblage from Ambitle is characterised by a large number of different vessel types such as restricted jars with everted rims and thickened lips, unrestricted bowls and pedestal stands that are highly decorated by dentate-stamping. All sherds analysed were formed by paddle and anvil, and the potter add mixed temper of volcanic crystals and calcareous sand. The ceramics were fired at high temperatures of 800-900 degrees Celsius, and a sherd from one vessel, possibly as high as 1000 degrees Celsius. The fact that the Ambitle ceramics could withstand such high temperatures is interesting since they contain a fair amount of calcareous sand, although mixed with volcanic sand. Adding salt water to the clay could possibly have reduced the risk of lime-blowing (Rye

1976:116-117). Most of the sherds are fired all the way through, indicating complete oxidation and the firing of about an hour or more.

The ceramic assemblage from Unai Bapot consists of small bowls with everted and direct rims, and sub-globular to ovoid restricted jars. The early Unai Bapot potters' choice of temper was calcareous sand (sometimes including quartz and volcanic admixture), which they added in large amounts ~19-35%. That calcareous sand is the *savoir faire* for the early potters in the Mariana Islands is quite clear since volcanic sands were readily available (including from drainages and beaches close to Bapot) and became a significant temper type in ceramics made after 2000 BP. The Bapot potters were able to form vessels with very thin-walls by paddle and anvil technique, and fired them at low temperatures of 600-700 degrees Celsius. The core of the pottery is dark grey to black indicating that the Bapot potters fired the ceramic under reduced conditions for a short period of probably less than an hour. The firing atmosphere can be controlled in various ways, and in the case of the Bapot ceramics, the potters probably fired the ceramics in a pit which could be sealed, perhaps with soil or sand.

The ceramic analyses presented above show that there is significant variation between pottery assemblages from different sites in ISEA and the Pacific, but it also highlights some similarities. Sites in west Sulawesi and the Karama Valley have a much closer affinity to Taiwan and northern Luzon than sites to the east, such as the Talaud Islands, Moluccas and western Micronesia. The study also shows that there might be pattern of similar vessel types and manufacturing methods in a north-south belt from the Talaud Islands, East Timor, to western Micronesia in the east, and Borneo and Bukit Tengkorak, to the west. This emerging pattern will be discussed in the next chapter.

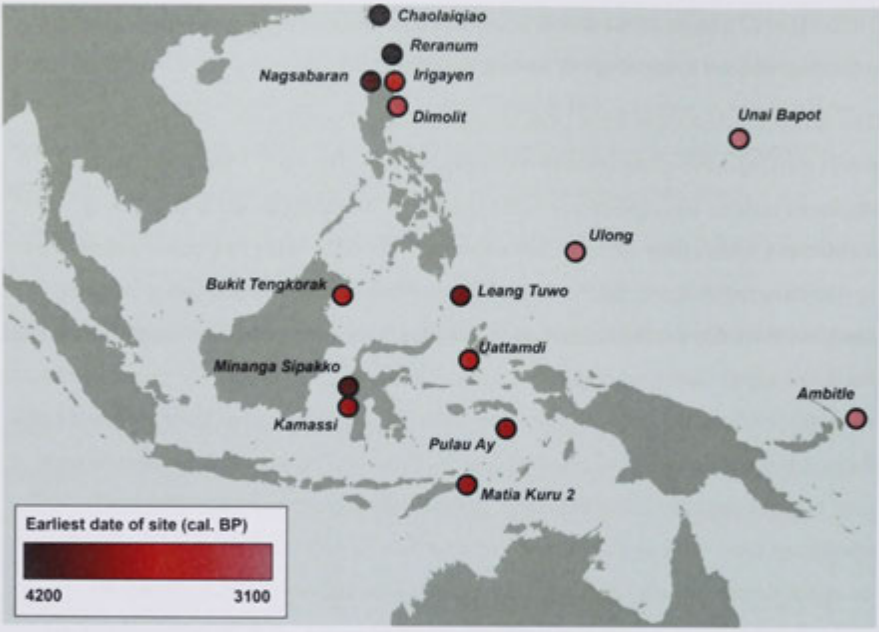


Figure 84. Earliest dates of ceramic assemblages in ISEA and the Pacific.

Figure 85. Distribution of vessel types in ISEA and the Pacific.

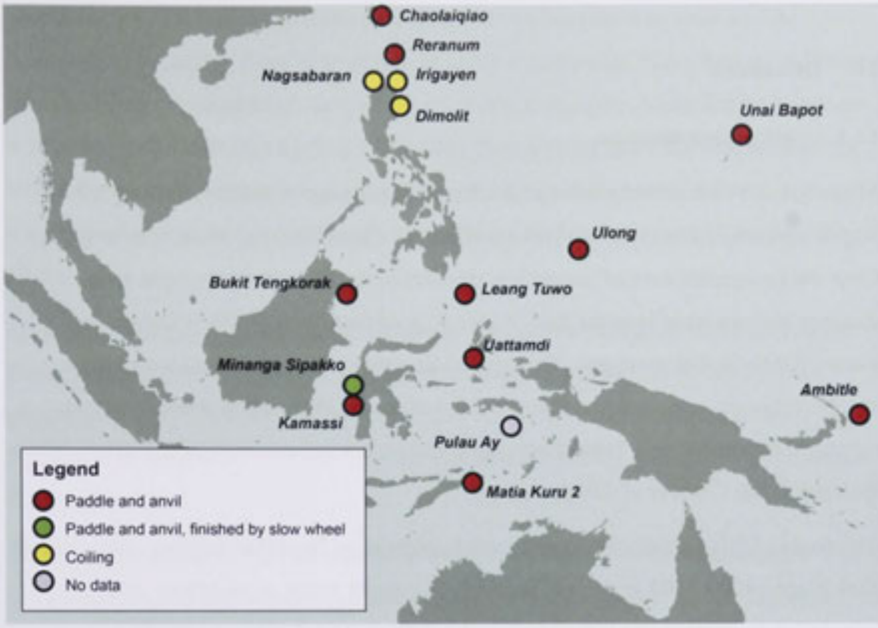


Figure 86. Different manufacturing techniques in ISEA and the Pacific.

Figure 87. Different temper material in ISEA and the Pacific.

10. Discussion

10.1. Migration theories

Migration is a common explanation to account for change in the past. Human history began with migration(s) out of Africa and human dispersals have since been ongoing. Over the geographic area of research in this thesis, the first relatively rapid long-distance movement of humans from Africa to Asia and Australia-New Guinea took place 70,000-50,000 years ago. This migration is thought to have used 'corridor' coastal/estuarine environments that provided migrants with predictable subsistence returns and required only limited economic and technological adaptions (Mellars 2006; Bulbeck 2008; Clark *et al.* 2010).

The focus of this thesis is the more recent hypothesised Neolithic farming dispersal that took place ~4000-3000 years ago, resulting in a major phase of migration and population mobility in the Indo-Pacific area. This dispersal of humans took place in both inhabited ISEA and the New Guinea region, but also resulted in the expansion of human groups over thousands of kilometres of ocean including the distant and previously uninhabited islands of Remote Oceania. In less than a couple of hundred years, an area of ~10 million square kilometres of land and sea had been covered (See Figure 3), including the settlement of islands in western Micronesia and Melanesia.

Current models of this expansion have previously considered migration from a regional perspective, as with the dispersal of Lapita populations from the west Pacific as far as Fiji and west Polynesia, or the migration of Austronesians from Taiwan through ISEA (Kirch 1997; Bellwood 1997). Recently, archaeological research has focused on the linkages between these two human dispersals, and suggested a strong connection between Neolithic sites in island Asia, particularly Taiwan, sites in northern Luzon and the Marianas, and sites in the Marianas and the Bismarck Archipelago (Hung *et al.* 2011; Carson *et al.* 2013; Carson 2014).

The significance of such a dispersal route, separated by 3400 kilometres of open sea, involving two long-range passages (northern Luzon-Marianas-Bismarck Archipelago), perhaps lies not in ancestral relationships, but in the understanding that a significant maritime capacity was needed to reach the Marianas, implying the possibility of an additional passage from the Marianas to the Bismarck Archipelago. For example, if people had an ocean-going technology capable of reaching the Marianas and the Bismarck Archipelago, there is no reason to assume that within ISEA they would have dispersed only via sequential, short-range inter-island voyages. A conflicting argument is that the maritime knowledge and technology that allowed colonists who reached the Marianas to sail the longest passage against prevailing winds, seems to have disappeared during the Lapita era only to re-emerge two millenia later (Winter *et al.* 2012).

Very long passages did occur in the Pacific and in east Polynesia, as in the movement from the Marquesas to Hawai'i (~3600km), but only after 1200 cal BP. In a global perspective, this is one or two centuries before the Norse expansion from Iceland via Greenland to America (~2500km) by Leif Eriksson around the year 1000 AD (Graham-Campbell 1994).

The orthodox model of the first migration in the Indo-Pacific is Peter Bellwood's 'Out-Of-Taiwan' hypothesis featuring an early agricultural dispersal by 'demic diffusion' involving a food producer 'wave of advance' extending or leapfrogging, and mixing with forager populations (Bellwood 2011:364). This model was originally developed to explain population transition and expansion during the Neolithic in Europe, where it was assumed that agriculture spread at the continental scale by dispersing farming populations, moving west from a home in the Near East (Ammerman and Cavalli-Sforza 1971, 1973, 1984; Renfrew 1987). Both these early farming dispersal hypotheses are multidisciplinary concepts that correlate prehistoric population spread with language dispersal caused by the development of agriculture. In the Indo-Pacific, human dispersal is tightly linked to the spread of Austronesian languages, and for Europe dispersal has been linked to Indo-European languages (Renfrew 1987, 1994, 1998; Bellwood 2005, 2011).

The demic diffusion model, the wave and advance model, and the link to Indo-European languages in Europe have been heavily criticised by a range of researchers from different scientific disciplines, and archaeological, genetic and linguistic research on Indo-European origins has so far proved inconclusive. Whilst numerous theories of Indo-European origins have been proposed, they have proven difficult to test (Zvelebil 1986, Mallory 1989; Atkinson and Gray 2006).

10.2. Linguistic evidence

In contrast to a long unanswered question about the origin of the Indo-European languages, the origin of Austronesian languages is fairly well established. The linguistic record clearly indicates Taiwan as the origin of Austronesian languages, since nine of the ten primary branches of the linguistic family are found exclusively in Taiwan and constitute the first order subgroup of the Austronesian language family. The tenth branch including the Taiwan Yami language, belongs to the Malayo-Polynesian group and comprises ~1200 separates languages spoken in ISEA and in almost every island in the Pacific (Blust 1984-1985; 1995).

The Austronesian language dispersal identified by Shutler and Marck (1975) and more so Bellwood (1978), was the 'skeleton' structure that became known as the 'Out-Of-Taiwan' model, as set out in the Early Agricultural Dispersal Hypothesis. The hypothesis proposed that a Neolithic-type economy was the driving force behind an ISEA version of Childe's Neolithic Revolution (1925), founded in a single dispersal with a very clear directionality and sequence. Pottery found in various archaeological sites in ISEA became the evidence for the models articulated in the 1970s.

Bellwood, in his 'Out-Of-Taiwan' model, directly correlated Austronesian language spread with the development of a red-slipped pottery tradition (Bellwood 2000). The red-slipped pottery is thought to be a material indicator of a southward spread of the "Austronesians" through the Philippines, and thence to Borneo and the Indonesian islands to the east. This has been the most highly supported explanation to account for the introduction of early pottery in the region (Swete Kelly and Winter 2015). Recently, new layers have been added to this 'Out-Of-Taiwan' model. Authors have argued, based on similarities in ceramics, for migrational flow between the Northern Philippines and the Marianas, with subsequent influence between the Marianas and the Bismarck Archipelago, in addition to Austronesian movement through the Southern Philippines and Indonesia (Hung *et al.* 2011; Hung *et al.* 2013; Carson *et al.* 2013).

10.3. Rate of dispersal

In contrast to the European Neolithic, the hypothesised 'Neolithisation' of ISEA and the Pacific was extremely rapid. For Europe, it has been estimated that the spread rate of farming populations was 1.0 km/year with beginnings in the Near East around 9000 cal BP and reaching southern Scandinavia about 6000 cal BP (~3200 kilometres) (Fort *et* *al.* 2012). For ISEA, radiocarbon dates indicate that the Neolithic extended from Taiwan to south Indonesia (Maluku) by 3500 cal BP, which gives anaverage of 5.2 km/year (Clark *et al.* 2010:31). For the Pacific, an average dispersal rate of 8 km/year from Mussau in the Bismarck Archipelago to Samoa in western Polynesia has been estimated (Fort 2003). The dates of first Lapita appearance in the Bismarck Archipelago have been debated for many years, with an emerging view that the Lapita arrival in the Bismarcks is a few centuries later, at around 3300-3200 cal BP (Denham *et al.* 2012; Sumerhayes 2007,; Torrence and Specht 2015). A younger chronology for first Lapita settlement in the Bismarck Archipelago would further increase the expansion rate of Lapita dispersal in the Pacific.

While estimates of the dispersal rate like those noted above might be useful for understanding the overall speed of colonisation, and may be accurate for the Pacific where settlers arrived in areas with no previous populations, they might provide a misleading picture of events like the start of the Neolithic in an already populated set of islands. Archaeological finds from Taiwan suggest an agricultural (rice and foxtail millet) economy from about 4800 cal BP for the Dabenkeng culture of southwestern coastal Taiwan (Bellwood 2011:368). Population pressure is the most common explanation for migration in other parts of the world and the Austronesian expansion is no exception. Bellwood, for example, argues: "that increasing populations must either seek fresh land or intensify production in order to survive and the former option would have been inviting in situations surrounded by lower density forager populations" (Bellwood 2011:364).

As opposed to the Neolithic expansion in Europe where there is clear evidence of a 'Neolithic package' involving cereal crops, including emmer wheat and barley which were not native to Europe and therefore had to be brought from Near East (Cunliffe 2001), the evidence of the agriculture that is thought to have fuelled the Austronesian expansion into ISEA is currently almost invisible. Evidence of rice cultivation is very sparse – it is found at a few sites dated between ~4000-2000 cal BP: two sites from Sarawak, Gua Sireh and Niah, and Madai and Bukit Tengkorak in Sabah; and from inclusion of rice husks in pot sherds at Andarayan, Luzon dated to around 2600 cal BP (Snow *et al.* 1986; Bulbeck 2008). A small number of *Oryza* spp. (wild or domesticated rice) have also been found in Neolithic contexts, ~3500 cal BP, from excavations at Kamassi and Minanga Sipakko in the Karama Valley, Sulawesi, but too few were found to establish whether rice was cultivated, or grew wild (Anggraeni *et al.* 2014:750; Anggraeni, 2012).

10.4. The link between pottery and agriculture

Pottery, of course, has been linked to Neolithic expansion since the time of Childe:

"[…] it is only in the Neolithic times that pot-making is attested on a large-scale; a Neolithic site is generally strewn with fragments of broken pottery" (Childe 1936).

It is true that pottery is one of two technological innovations (the other being polished stone axes/adzes) that frequently, though not always, accompanied early agricultural economies. But, current research suggests that there are several archaeological sites around the world where pottery was invented and used in a non-agricultural context or was adopted by hunter-gather societies, or was made by mixed hunter-gatherer/agricultural groups. For example, the early characteristic pottery known as 'Cardial Ware' (named as it was often decorated with the impressed edge of the *Cardium* shell), has been found at sites in Italy, Sicily, the Mediterranean coast of France, and southern Spain where it is dated to as early 9000-8000 cal BP. No Cardial Ware site has supplied evidence for domesticated animals or cereal growing, and it is very possible that local communities adopted pottery manufacturing (Cunliffe 2001:140).

Additionally, pottery with dates ranging from 15 000 to10 000 cal BP for China (Boaretto *et al.* 2009), Japan from about 15 000 to 11 800 cal BP (Craig *et al.* 2013) and 5500-5000 cal BP in the Brazilian Amazonas (Roosevelt 1995) among others, all predate the adoption of an agricultural lifestyle and indicate that there should be no *a priori* assumption linking the presence of prehistoric pottery with a farming economy.

Considering the very sparse archaeological evidence of broad-scale cultivation of grain crops (rice and millet) found in ISEA it is hard to argue that the movement of Neolithic material culture, especially pottery, is congruent with the movement of rice-agriculturalists and/or that agriculture was the driving force behind the dispersal of Austronesian populations (Swete Kelly 2015). Nevertheless, early evidence of rice and millet farming has been identified in Taiwanese archaeological sites (Tsang 2007) and might be linked to demographic growth. Rice and millet are found at the two Ta-pen-keng culture sites, Nan-kuan-li and Nan-kuan-li east, in Tainan county, western Taiwan (Tsang 2007). The sites are dated to ~5000-4300 cal BP, but archaeological records of faunal remains at both sites clearly show that marine foods together with terrestrial animals (dog, deer and wild boar) were probably central to the dietary system compared with crops (Bestel 2014).

A population rise could be reflected in the greater number of sites that emerged during Taiwan's middle Neolithic since more than 300 sites have been documented from this period (Carson and Hung 2014:508), but very few sites have documented archaeological evidence of rice/millet.

Agriculture in modern Taiwan is still very traditional. In 2004, about 8355 square kilometres of land or approximately 23% of total land (32 260 square kilometres) was being farmed by 721 418 households. Agricultural modernisation has been inhibited by the small size of farms. An average Taiwanese farming household consists of five people, which indicate that approximately 3.6 million people live off subsistence farming.[2]

A comparison between contemporary farming societies and prehistoric societies probably has little value and should only be used as a rough guide to population increase. However, if Taiwan could hold ~700 000 farming households, keeping ~3.6 million people living from farming on ~23% of Taiwanese land in modern times, it might seem doubtful that the introduction of a new version of subsistence agriculture at ~5000-4500 cal BP would lead to rapid overpopulation and migration.

A better example might be the Mariana Islands. In 1660, Father Sanvitore reported the population in the Mariana Islands to be 90 000 people (50 000 on Guam and 40 000 on the other islands of the archipelago). This figure is most probably an overstatement and a more detailed number was provided by Father Peter Coomans, a Belgian priest who arrived in the islands in 1674. Coomans estimated the total population as ~24 000 with 12 000 on Guam, 6000 on Saipan, 3000 on Tinian, 2000 on Rota, 300 on the small island Aguiguan, and 500 on the island of Anatahan (Russel 1998:125-126).

The total landmass of the 15 islands in the Mariana group equals 1008 square kilometres, which suggests a population density of ~24 people per square kilometre (several islands were not inhabited) after more than two millennia of habitation on the islands (Cooman's estimate did not, however, take into account the effects of disease,

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[2] "Taiwan." Food & Fertilizer Technology Center. Accessed October 25, 2015. http://www.fftc.agnet.org/view.php?id=20110705103744_104108.

warfare and colonial rule on the indigenous population). A similar population density in Taiwan would give a population of ~770 000 people.

The example indicates that an unsustainably high population at the dawn of agriculture appears highly unlikely, especially considering that the Dutch estimate of the Taiwanese population in 1650 was 68 576 aboriginals and that the Dutch actually had to bring in 15 000 Han Chinese for labour, since the colonial rulers could not convince enough aboriginal men to give up hunting and take up farming (Lee 2007:53; Martin 2006).

Considering the sparse archaeological evidence of substantial agricultural production (although refined archaeological techniques might verify agricultural driven dispersal in the future) that could have caused a demographic growth sufficient for the very rapid movement of large numbers of Austronesians, other factors should also be examined.

10.5. Other reasons for migration

Economic factors have traditionally been the focus of migration theories, while ideological factors might have been just as important (Anthony 1990:898). A useful example of a migration debate involving maritime dispersal relates to the cause of the Viking Age in the north Atlantic.

The late first-millennial period of conquest, raiding, trade, migration and colonisation known as the Viking Age has been an ongoing research issue. Different 'push' and 'pull' factors (discussed further below) such as climate and environmental factors, social or political change, technological development (especially maritime technology), population pressure, trade and ideological factors have been proposed (Ashby 2015).

Very similar 'push' and 'pull' factors have been proposed for the Austronesian expansion by researchers.

Solheim *et al*. (2006) proposed that similar Neolithic pottery and cultural traditions in ISEA are the result of trading activities and the migration of Nusantao traders. Solheim asserted that the earliest pottery in Southeast Asia and the Pacific belongs to the Hoabinhian pottery tradition found in coastal Vietnam and this tradition gave rise to subsequent pottery types that then developed into the Sa Huynh-Kalanay pottery and Lapita pottery traditions (see Chapter 2).

Anderson (2005) discussed whether it was the arrival of new maritime technology after 5000 BP or the arrival of agriculture that promoted the high mobility in ISEA in the late

Holocene. Anderson noted that: "Effective maritime technology is by no means tied to the expansion of farmers" (Anderson 2005:39-40). Furthermore, Anderson pointed out that climatic change might have played a substantial role in late Holocene population movement with the onset of modern ENSO periodicities and amplitudes around 4500-4000 BP. ENSO has been linked to northern drought and southern flooding in ISEA which may have 'pushed' people to migrate (Anderson 2005).

Spriggs (2003) proposed that elite dominance rather than demographic-subsistence or farming/language dispersal could be used to explain the rapid spread of Austronesians, but backed away from this theory in a more recent paper (Spriggs 2011a). In the 2011 paper Spriggs argued that the lack of Taiwanese derived agricultural evidence (rice and millet) in ISEA did not mean that a 'Neolithisation' had not taken place, since the process of 'Neolithisation' need not involve agriculture at all, and that the arrival of new ideas and artefacts, presumably by boats, played a more important role. He proposes that: "Neolithisation of ISEA was a new process of identity formation that seized the imagination of a mass of people on hundreds of islands across thousands of kilometres of ocean, spreading like a pulse across ISEA and into the Pacific over a few centuries. It spread through processes both of migration and recruitment in-place" (Spriggs 2011:523-524).

Roger Blench (2014) suggested that there must have been a 'social dynamic', something that motivated mariners to undertake highly risky voyages. Blench thinks a powerful religious ideology backed by iconography was responsible for the rapid Austronesian dispersal. He also argues that the Austronesian expansion was an agricultural revolution that failed, but that the dispersal succeeded anyway because the prehistoric economy was flexible enough to drop agriculture in order to disperse more effectively (Blench 2014:1-2).

Bulbeck (2008:32) similarily argues that Austronesians were 'terrestrially challenged' and intentionally switched from grain cultivation to root and arboreal crops that could be productively harvested with minimal tending, which allowed people to diversify and exploit the marine environment.

Combining the above theories suggests a view similar to the arguments put forward to explain the Viking Age, except that demographic growth is not such a key factor in Austronesian dispersal. This appears reasonable as the rapid spread of pottery in ISEA, and presumably also of Austronesian people, does not fit the demographic growth-agriculture subsistence model where people move in to an area, establish agriculture, expand their population and then the pattern repeats causing gradual expansion from the growth of more and more daughter communities. The Austronesians seem to have moved faster than a dispersal model in which local environments reached saturation resulting in community fissioning and the expansion of farming into new areas. In Europe, where agricultural dispersal is evident in finds of exotic crops and grains, populations seem to have moved much more slowly, which is consistent with a gradual 'wave of advance' dispersal. Anderson (2005) notes that farmers do not necessarily sail and indeed, demographic models for agricultural spread in Europe have shown that after agriculture arrived in Cyprus there was a delay in the spread of farming into Europe. Ammerman (2010a, 2010b in Fort *et al.* 2012) has suggested that marine foragers made visits to Cyprus and it was these people, not early farmers, who had boats and long-distance sailing capability in the Mediterranean.

The archaeological evidence for early Austronesian mobility clearly shows that they were maritime-oriented communities whose material culture was located on coastlines and along major river systems. These peoples were capable of sailing substantial distances over open water and at a broad level there were material culture traits and probably a similar language/dialect chain that was maintained for some time over a large area.

From archaeology, linguistics and genetic research we know that there was migration out of Taiwan into ISEA, perhaps via the Batanes Islands, into the northern Philippines (Kayser *et al.* 2008; Bellwood 2011; Spriggs 2011). Around 4200-4000 cal BP, red-slipped pottery appears in the previously uninhabited Batanes Islands in Reranum and the Torongan Caves, and then very soon after ~4000 cal BP, it appears in northern Luzon (see Chapter 2 for a different view on these early dates) at sites in the Cagayan Valley such as: Gaerlan 4090-3690 cal BP; Irigayen 3450-3000 cal BP; Magapit 3350-2690 cal BP; Andarayan 3935-3060 cal BP ; Nagsabaran 3980-3360 and Dimolit 3230-2690 cal BP (all dates recalibrated using Calib 7.0.0., 2-sigma range, and note that many results have a large standard error; Hung 2008).

From northern Luzon, it seems that population expansion was rapid with red-slipped pottery found over many parts of ISEA in just a few centuries (see Figure 84). Red-slipped pottery is first found at around 3500-3300 BP in many sites: 3550-3370 cal BP from Leang Tuwo Mane'e rock shelter in Talaud Islands (Bellwood 1976; Daud 2001);

3650-3460 cal BP from Minanga Sipakko and 3380 -3495 cal BP Kamassi, in Karama Valley, Sulawesi (Anggraeni *et al.* 2014); 3410-2842 cal BP, 3185-2970 cal BP at Bukit Tengkorak, Borneo (Bellwood 1989); 3570-3010 cal BP at Uattamdi, Kayo Island, Moluccas (The 14C sample is on marine shell. No ΔR is provided, but the date is indicated to be ~3300 cal BP; Bellwood 1992:54-58; Irwin *et al.* 1999); Site PA 1, Pulau Ay, Banda Islands 3500-3400 cal BP (Peter Lape, personal communication April 2014); and ~3500 cal BP at Matja Kuru 2 (Sue O'Connor, personal communication Jan. 2015).

Recent research by Hung *et al.* (2011) and Carson *et al.* (2013) suggests, based on ceramic similarities and site dating, that the Mariana Islands belong to the very first off-shoot of colonists from northern Luzon and that the first humans arrived with red-slipped pottery at ~3600-3500 cal BP. Research presented in this thesis and elsewhere (e.g. Winter *et al.* 2012) does not support either proposition.

10.6. Red-slipped ceramics

In Chapter 2, it was noted that the ceramic evidence for migration in ISEA is very different from that of the Lapita expansion. Lapita migration spanned 2700 linear kilometres in ~400-300 years (Bismarcks-Vanuatu), including already inhabited islands in the west Pacific. The ceramic similarities of this migration are unmistakable and include similar vessel forms, decoration methods, and importantly the design system applied with dentate-stamping and incision tools.

For ISEA, ceramics have mostly been viewed as an indicator of Austronesian expansion, and are discussed as a chronologically coherent regional tradition, based on the presence of red-slipped pottery. Although there have been many studies completed throughout ISEA that describe the pottery obtained from one or several closely related sites, few detailed attempts have been made to understand the similarities and differences of the early pottery across the broader region. In contrast to European or Pacific archaeology, few studies have attempted to use quantitative and qualitative measures to formally assess the relationships between ceramic assemblages in terms of production and style. Comparisons between different ceramic assemblages are mostly generic rather than specific, yet despite this, models for migration in ISEA rely heavily upon arguments concerning the distribution of poorly defined pottery types (Swete Kelly and Winter 2015).

The analyses of pottery presented here was designed as a first step to compare in detail, different assemblages that have been argued to be belong to an Austronesian pottery tradition that was spread by an expanding population. Rather than subjectively extracting a small set of simple ceramic traits to determine similarities and identify prehistoric migration, I have determined specific attributes including vessel form, raw material choice and manufacturing techniques, to quantify inter-assemblage variation. In other words, the study aim was to assess both ceramic similarity and ceramic dissimilarity. The only similar study that I am aware of is Swete Kelly's 2008 dissertation, where she analysed the assemblage variation among eleven early pottery sites in the Cagayan Valley, the east coast of Luzon, the Batanes Islands, and Taiwan. Swete Kelly examined elements of pot form, surface modification, firing characteristics and fabric characterisation. Both my own results and Swete Kelly's studies have confirmed that there are only generalised similarities between many red-slipped pottery assemblages that are said to be highly similar or that are claimed to be directly related to one another.

10.7. Radiocarbon dates from the Mariana Islands

As outlined in Chapter 1, the main aim of this thesis was to answer three rather essential questions about the prehistoric movement of people from ISEA to western Micronesia:

- When were the Mariana Islands first colonised?
- Where did the original settlers of the Mariana Islands come from?
- What factors stimulated the movement of people from ISEA to the Mariana Islands in Remote Oceania?

The colonisation of the Mariana Islands has often been placed at 3500 cal BP or slightly earlier (Spoehr 1957; Spriggs 2011a; Carson 2014). Establishing the age of initial colonisation in the Marianas is important, as human arrival at ~3600-3500 cal BP suggests that occupation predates Lapita colonisation of the Bismarck Archipelago, and the possibility that large ocean passages were made at the dawn of Austronesian expansion speaks to a well-developed marine technology that was capable of making the longest ocean voyages at that time anywhere in the world.

The Unai Bapot site has recently been interpreted as the earliest securely dated site in the Mariana Islands with an estimated age of 3559-3514 cal BP (Carson 2014:38). I disagree with this early age estimate for the Unai Bapot site. The age estimate derives from shell samples (*Anadara* sp.) that were rejected by Clark *et al.* (2010) since they were suspected to be on shells that were either altered by fire, or affected by hard water from the limestone substrate of Saipan Island (for full details see Chapter 7.5).

The 2008 excavation at Unai Bapot generated a new set of radiocarbon dates as reported in Clark *et al.* (2010), and an additional set of 21 samples on short-lived plant taxa, extinct bird bone and shell artefacts has also been recently dated. The latter dates will be presented elsewhere, but they clearly indicate that dates on *Anada*ra *antiquata* at Unai Bapot are too old, suggesting the presence of a significant hard-water effect. This implies that marine samples need to be used cautiously to date human arrival on carbonate islands in the Marianas. Extensive radiocarbon dating of the Unai Bapot site suggests a more recent date than other research (such as Carson 2008; 2014; Carson and Kurashina 2012) and the most likely estimate for human arrival is ~3200-3100 cal BP.

There are seven other sites in the Mariana Islands (see Chapter 6) which have a total of 46 14C samples from before 3000 cal BP. Only dates with the earliest date range (older than 3100 cal BP) are discussed (except Beta-62605, from Unai Chulu), to see whether the revised Bapot age is consistent with other age results.

- Achugao on west coast of Saipan has two early dates from the lowest layer that are distinctively different from each other; Beta 36190 calibrated to 4005-3451 and Beta-3619 at 3447-3213 cal BP. Both samples are on unidentified charcoal and could be influenced by in-built age.
- From Chalan Piao, Saipan, Moore *et al*. (1992) present an early date of 3644-3205 cal BP (Beta-33391). The excavators could not find sufficient intact charcoal, so unidentified charcoal fragments were combined from several locations and the context and possibility of inbuilt age indicate the 14C age may not be reliable.
- Two excavations at Unai Chulu on Tinian have been carried out, and Craib (1983) reports early dates obtained on *Anadara* shell of 3978-3317 cal BP (Beta-62603) and 3552-2980 cal BP (Beta-62605); both dates have very large date ranges of ~600 years. Haun et al. (1999) reported three early dates on charcoal 3447-3213 cal BP (Beta-81946), 3447-3165 cal BP (Beta 81948) and 3379-3206 cal BP (Beta-83213). Beta 81948 is identified to *Ficus* sp., which is a relatively long-lived strandline taxa, meaning charcoal from it could contain an inbuilt age,

and the other two samples are from unidentified charcoal and so might also contain some inbuilt age (Clark *et al.* 2010:30).

- From the House of Taga on Tinian, Carson reports two early dates on *Anadara* sp. of 3604-3144 cal BP (Beta-313868) and 3625-3167 cal BP (Beta-316284). Ritidian on Guam, also excavated by Carson has several early dates on *Anadara* sp., but only one date may be older than 3100 cal BP. Another sample (Beta-253682) on *Halimeda* sp. bioclastic sand dated to 3615-3135 cal BP. The use of *Halimeda* sp. as a dating material is questionable since it has no cultural association, and there is also a significant possibility that it is subject to the hardwater effect. As such it is probably not a reliable material to establish the antiquity of human arrival.
- From the Mangilao Golf Course site on Guam there are several early dates, with one (Beta-53472), on unidentified charcoal dated to 3483-3209 cal BP, where inbuilt age is a possibility.

In total, 11 radiocarbon samples out of 46 from different sites in the Mariana Islands have a two-sigma lowest date range that cannot be interpreted as younger than 3100 cal BP. All of these dates should be treated with some suspicion, since they are on unidentified charcoal which might contain inbuilt age, or are on long-lived species, derive from unclear contexts, comprise mixed samples or are on material that has proven difficult to date, as with *Anadara* sp. shell that has proven to be constantly older than other ages on other materials. Several of the 46 dates have large standard errors, but the majority of early dates from the Mariana Islands are consistent with human arrival around 3200 years ago.

10.8. Colonisation of the Mariana Islands

Recent archaeological research has claimed a strong connection between Neolithic sites in island Asia, particularly Taiwan, northern Luzon and the Marianas, and also between sites in the Marianas with Lapita assemblages in the Bismarck Archipelago. Based on comparison of the small component of decorated pottery from the Nagsabaran site in the Cagayan valley and the small component of decorated pottery from early sites in the Marianas, it has been argued that the colonisation of the Mariana Islands resulted from an early migration from the northern Philippines. This migration took place just a few hundred years after the initial Austronesian dispersal out of Taiwan to the Philippines, and people are proposed to have arrived in the Mariana Islands about 3500 cal BP or slightly earlier (Hung *et al.* 2011; Carson *et al.* 2013; Carson 2014). Shortly after this initial colonisation of the Mariana Islands, it is suggested that a second migration from the Mariana Islands to the Bismarck Archipelago took place, introducing the dentate-stamped, red-slipped pottery that is so characteristic of early Lapita culture (Carson 2014; Carson *et al.* 2013).

A Philippines homeland for the first settlers of the Marianas is not an entirely new idea and has been proposed by several archaeologists for almost fifty years. Sites in the Philippines that have been suggested as having a close cultural material relationship (especially pottery) with the Mariana Islands include: the Batungan caves on Masbate (Solheim 1968), Sanga Sanga rock shelter in the Sulu Archipelago (Spoehr 1973), and the Cagayan Valley shell middens at Lao-Lao in northern Luzon (Thiel 1986-87; Aoyagi *et al.* 1993; Hung 2008). Kalumpang in western Sulawesi has also been suggested as having similar material culture to the Mariana Islands (van Heekeren 1972). However, this idea has not been accepted by all archaeologists working in the Marianas. Archaeologists such as Brian Butler and John Craib who have worked extensively in the Marianas have noted that "the similarities are generic rather than specific, and are usually limited to a few of the decorated sherds" (Butler 1994:34). Craib is of similar opinion: "general parallels with the early decorated ware in the Marianas can be found within several areas of Southeast Asia. Virtually anywhere between Taiwan and southern Indonesia will exhibit similar pottery designs" (Craib 1999:482).

Neither are the similarities between Mariana Island ceramics and Lapita pottery a new discovery, they have been noted in earlier research, although no one has previously suggested Lapita ceramics could have derived directly from the Marianas. In contrast, Butler notes: "It is now obvious that the early Marianas ceramics are not related to Lapita ceramics, although they both derive ultimately out of the same general milieu of late Neolithic cultures in Island Southeast Asia" (Butler 1994:35). To Spriggs (1999), the evidence of early dentate-stamped pottery in the Marianas provides the 'smoking gun' for deliberate migration voyages of pottery-using people out of ISEA, rather than having the Lapita culture developing locally in the Bismarck Archipelago.

The new dates from Unai Bapot, however, suggest that rather than being an earlier colonisation than Lapita colonisation of the Bismarck Archipelago, they may be contemporaneous. A younger chronology for the Mariana Islands also makes human arrival in Palau at ~3100-2800 cal BP (Petchey and Clark 2011; Clark *et al*. 2006) very much closer in time. Additionally, Irwin's (2000) hypothesis regarding Mariana colonisers utilising either Palau or Yap, or both, as stepping stones does not seem so far-fetched anymore, although no current archaeological data from artefact studies nor historical linguistics support such a route.

These differences suggest that there might have been multiple movements of different Austronesian-speaking groups out of ISEA into the Pacific, although Irwin (1992) warns that contemporary linguistics may only reflect the most recent pre-European contact history and might not be a good indicator of prehistoric origin. Neither Palau nor Yap appear to have been isolated islands before Europeans arrived; glass beads found on Palau and Yap indicate contact with ISEA, and inter-island contact is evident from Yapese stone money quarrying on Orrak Island in Palau (Fitzpatrick 2003; Rainbird 2004).

Although Blust states: 'Neither archaeological nor linguistic evidence supports the view that there were two or more major migrations to the Marianas' (Blust 2000:109), there *is* archaeological evidence that clearly points to interaction with ISEA at ~1000 BP. This evidence comprises the use of megalithic *latte* stones, the introduction of rats and probably rice which may be associated with the prestigious basalt mortars (*lusong)*, commonly associated with *latte* settlements (Rainbird 2004).

The antiquity of rice in the Marianas has been debated and there are hints that rice and *lusong* first appear during the Latte period (see Chapter 6.4), but linguistic results tend to muddy the waters. Blust assigns all Chamorro words associated with rice to Proto-Austronesian: "The etymologies *pajay > *fa'I'* rice in the field, rice plant', beRas >*pugas* 'uncooked rice', and *lesung > *lusong* 'rice mortar [….] all three terms are directly inherited from Proto-Austronesian and so indicate an unbroken continuity in the tradition of rice cultivation" (Blust 2000:109). This means that ~2000 years of rice cultivation in the Mariana Islands has not been detected by archaeologists, or that rice cultivation arrived together with rats and perhaps the *latte* architecture at a later date of ~1000 BP.

Both of these propositions have serious flaws. First, if the word *lesung > *lusong* refers to mortars made out of stone, then archaeologists would certainly have found them. However, there is no record of early stone mortars in the Marianas although stone pounders do occur in colonisation-era sites such as Bapot. Second, if rice was introduced to the Marianas at ~AD 1000 then how is it that reconstructed words associated with rice farming in the Marianas are associated with Proto-Austronesian, which is several millennia older? My critique of Blust's theory on Chamorro origins (see Chapter 4.4) casts doubt on whether historical linguistics alone is a useful tool to track early human dispersals, and whether alternative migration routes should be dismissed just because some linguistic data does not match the archaeological record.

10.9. Mariana Island ceramics

There are eight Early Pre-Latte ceramic assemblages reported from various sites in the Mariana Islands: Achuago, Saipan; Unai Bapot, Saipan; Chalan Piao, Saipan; Unai Chulu, Tinian; House of Taga, Tinian (although no full report is available, some data is presented in Carson 2014); Ritidian, Guam; Tarague, Guam and Mangilao, Guam. These assemblages are remarkably homogenous; they all consist of the same vessel types (when small differences between vessels are noted, it is probably because different archaeologists have drawn the sherds, rather than actual differences), have a calcareous sand temper with some quartz/volcanic tempered sherds, and consistently contain a small number of decorated sherds of the two dominant early décor styles, Achuago Incised or San Roque Incised, although often less than 1% of an excavated sherd collection.

There is some uncertainty about whether the two decorative styles are contemporaneous. The two styles consistently co-occur at Achuago in the earliest layers of the site (Butler 1995). At Unai Bapot, Carson reported that the earliest layers did not yield decorated potsherds and that the extreme paucity suggests a possible sampling error. At House of Taga, he reports San Roque being later than Achuago Incised (Carson 2008, 2014). The 2008 Bapot Block A excavation found small quantities of both decorative styles in the earliest layers (see Chapter 7).

No excavation report encountered during research in this dissertation describes any differences or large deviations between the Unai Bapot pottery and that from other early sites in the Marianas. There are no observations that indicate experimentation in pottery manufacturing techniques was present during the first settlement phase of the Mariana Islands, although Carson (2014) speculates that several different methods were used when manufacturing pottery in the Marianas, including slab and coil-building finished by trimming. Carson notes: "Primary forming has been curiously difficult to specify in the earliest Mariana pottery, because diagnostic forming-features occurred in less than 1% of the examined collections. Later secondary forming may have obliterated traces of the original shaping, along with any potential flaws and weaknesses" (Carson 2014:56).

In short, Carson did not find either primary forming or secondary forming features except for some sherds with paddle marks, which are extremely rare in the earliest Mariana pottery assemblages. My manufacturing study used a thin-section method to identify the pot-forming technique. Most of the sherds studied showed obvious traces of paddle and anvil technique, and there is clear evidence that potters added a coil at the top of the pot to produce the lip. Two sherds from younger ceramics at Unai Bapot were clearly made with the coiling technique, and both belonged to thick walled vessels, one incurved bowl classified as I3 in layer 1 and one unrestricted vessel with direct rim. Both vessels are typical for the Latte-period although sherd 76:5 classified as D2 was found at a depth of 120-130 cm and might be intrusive to that layer.

The focus of this thesis was the oldest ceramics from Unai Bapot and most of the intensive analyses were carried out on ceramics from the early portion of the site. Two of the three analysed sherds from younger layers had no visible pores and it is therefore unclear when a possible transition from exclusive paddle and anvil shaping to some coiling may have occurred. May and Tuckson (2000: 7) noted in their study of contemporary ceramic production in Papua New Guinea that coiled vessels tend to be thick-walled and heavy, and often in the case of cooking pots were crudely made. This observation fits well with sherds manufactured by coiling identified in my analyses. The same authors also note that in Papua New Guinea, the paddle and anvil technique was used exclusively in coastal areas by female potters and coiling method was the dominant technique used in inland areas, where in the majority of cases, men were the potters. There is of course no way of telling if potters in the prehistoric Mariana Islands were male or female, but the possibility of gender differences in ceramic manufacture is intriguing (May and Tuckson 2000; Pétrequin and Pétrequin 2006).

The ceramic assemblage from Unai Bapot shows that the people who manufactured pottery started to do so as soon as they arrived in LauLau Bay, ~3200-3100 years ago. Ceramics are reported in the oldest cultural layers at every early site in the Mariana Islands (Butler 1995; Moore *et al.* 1992; Liston 1996; Dilli *et al.* 1998; Haun *et al.*

1999; Carson and Welch 2005). Finds of clay and red ochre together with what could be an anvil stone (see Figure 55, Chapter 7.8) from the earliest layers are clearly indicative of onsite manufacture. Just as they explored the environment and found suitable material to manufacture stone tools, the first settlers also found appropriate clay and ochre sources.

As mentioned in the ceramics section (Chapter 7), there is suitable clay for pottery manufacturing directly behind the Unai Bapot site. This is also the case with the two other Early Pre-Latte sites at Saipan; both Achuago and Chalan Piao are in close proximity to suitable clay sources. While this could be a coincidence on a small island like Saipan, it cannot be ruled out that being close to an important raw material was of importance when choosing where to settle. The choice of calcareous temper is curious (see Chapter 7.6.3) considering that there are volcanic sands in the immediate vicinity of Unai Bapot (see Figure 45, Chapter 7.6.3), which gives weight to the idea that the use of calcareous sand was a deliberate choice rather than geological chance.

It has been demonstrated that due to thermal expansion patterns that are similar in most common clays, calcium carbonate is beneficial for pots used in cooking (Rye 1976:116-117). Further support of this is found in the late William Dickinson's Petrographic Report WRD-285 (June 2010), where he speculates that the Unai Bapot pottery makers were collecting their calcareous hybrid temper sand at the coast near Puntan Halaihai where southward longshore drift under the influence of the prevailing trade winds built up hybrid beach sand against the barrier of the Puntan Lau Lau-Puntan Hagman headland. Punta Halaihai is only three kilometres away from Unai Bapot, but this is an indication that temper-sand of a particular type was important to potters. Unai Bapot was a beach when people first arrived and presumably there should have been plenty of temper material close by. This was observed by Clark and Winter who collected volcanic placer beach sand derived from the local drainage in front of the Unai Bapot site (see Figure 46, Chapter 7.6.3), and Dickinson who collected placer sand just to the north of the same beach. However, neither sand precisely matches the temper in any of the sherds that were petrographically analysed by Dickinson (2010) (in Appendix1:121).

From the manufacturing study, together with the conventional study of ceramics, it is evident that the first settlers of the Mariana Islands arrived with a fully developed idea of how ceramics should be manufactured based on their existing *chaîne opératoire*.

They probably did not experiment with new materials nor attempted to develop a new ceramic 'recipe', but instead sought to produce pots using the methods they used previously in ISEA. The new arrivals, of course, had to find the right clay resources and the right temper materials, but having done that, they modelled their vessels as they had always done, with paddles and anvils. They decorated a few of them with two distinctive design systems, the Achuago Incised and the San Roque Incised. They were aware that clay with added calcareous temper must be treated with care while firing. The early Unai Bapot potters also seem to have had a conservative attitude toward their choice of temper, clay and vessel forms, as these stayed the same for a period of perhaps 500 years (calcareous temper lasted even longer). The same trend was noted by Butler (1995), when he studied the early calcareous ware deposits from the Nansay tract excavation. The deposit of early calcareous ware there spans a period of 500 years and no temporal variation was detected in that time (Butler 1995:202).

10.10. How similar is similar enough?

In the manufacturing study described in Chapter 9, sherds from Unai Bapot were compared to sherds from Nagsabaran as well as to sherds from three other sites in the Indo-Pacific region: Chaolaiqiao in Taiwan; Ulong, in the Republic of Palau and Ambitle in the Bismarck Archipelago. The purpose was to determine whether or not there was a homogenous ceramic craft tradition in the region during the period ~4000-3000 BP. An additional nine Neolithic ceramic assemblages from different sites in ISEA were also studied (from published data) as comparison material, these were: Batanes Islands; Irigayen, Philippines; Dimolit, Philippines: Leang Tuwo Mane'e rock shelter in Talaud Islands; Minanga Sipakko; Kamassi, in Karama Valley, Sulawesi; Bukit Tengkorak, Borneo; Uattamdi, Kayo Island, Moluccas and Matja Kuru 2, East Timor.

The manufacturing study (Chapter 9) shows that the potters at the different sites all had their own *savoir faire* and followed their own *chaîne opératoire*. There is significant variation between the different assemblages and there is no clear evidence for a direct migratory link between any of the early ceramic assemblages examined, as had been previously proposed (Hung *et al.* 2011; Carson *et al.* 2013; Anggraeni *et al.* 2014). Where there are similarities there are also differences which should not be ignored.

Nevertheless, there are some aspects in the different ceramic assemblages that indicate generic relationships between sites. As seen in Chapter 9, ceramics from Chaolaiqiao, Taiwan; Reranum, Batanes Islands and from Nagsabaran, Irigayen and Dimolit in northern Luzon, tend to have more similarities with each other and with ceramics from the Karama Valley, Sulawesi, than with the ceramics from any of: Bukit Tengkorak, Sabah; Leang Tuwo Mane'e, Talaud Islands; Uattamdi, Kayo Island, Moluccas; Matja Kuru 2, East Timor; Ulong, Palau and Unai Bapot, Mariana Islands.

Similarly, the latter assemblages show closer affinity with each other than with the former. Leang Tuwo Mane'e, Uattamdi, Matja Kuru 2 and Unai Bapot contain a very thin red ware with the smallest body sherd thickness of only 1-3 mm and these vessels were manufactured by paddle and anvil, and tempered with calcareous and sometimes volcanic sand. The vessel forms show more affinity with each other than with northern Philippines or Karama Valley vessels, and there are no documented vessels with concave rims or very sharp everted rims (except P and Q, Leang Tuwo Mane'e, see Figure 83). Calcareous temper sand is also common in the sherds from Palau and Ambitle and many Lapita sites, and is also reported from an early assemblage of red-slipped pottery from Site PA 1, Pulau Ay, Banda Islands dated to 3500-3400 cal BP (Peter Lape, personal communication, 2014). Unfortunately, detailed data relating to these assemblages is still largely unpublished and except for the Matja Kuru 2 material, I have not analysed it myself. However, the published data is intriguing and could indicate a south-eastern Island Southeast Asia tradition of pottery making that involves the Talaud Islands in the north, through the Moluccas, down to East Timor in the south and out to the Pacific to the east.

Given the rapid ceramic dispersal evidenced by radiocarbon dates (see Figure 84), it appears that red-slipped ceramic existed over the whole ISEA region around 3500 cal BP, so how does it happen that the ceramics are not highly similar? If it was the case that people were expanding into new, unoccupied regions and producing pottery as they would in their homelands, we would expect a much higher degree of similarity in pottery technique and forms reflecting their mental and technological habitus (e.g. Barley 1994; Gosselain and Livingston Smith 2005; Larsson and Graner 2010). This is seen, for example, in Vanuatu, where ceramic assemblages dated to ~3000-2900 cal BP are immediately recognisable as similar to Lapita ceramics assemblages in the Bismarck

Archipelago dated 300-200 years older and 2700 kilometres away (Bedford, personal communiation, February 2014).

Reasons for ceramic change are problematic for archaeologists since we often only recover fragmentary evidence of the societies we study. Ethnographic studies provide one strategy for investigating what causes ceramic change. Such an approach assumes a basic similarity between observed changes in contemporary material culture systems and the processes responsible for ceramic change seen from archaeological data (Stark 1991; Arnold 1987).

There are hundreds of publications and books explaining ceramics, ceramic technology and ceramic change both from an archaeological point of view and from an ethnographic stand point. For this thesis, there are two studies that I think best summarise the numerous explanations for ceramic change that are especially relevant.

Miriam Stark (1991) has studied ceramic change in the Kalinga area in northern Luzon, Philippines for over two decades and has noticed that ceramic change in the Dalupa community is a by-product of broader socio-political, environmental and ecological changes that occurred in the area. These changes have led to stylistic variation in extant vessels, a wider range of ceramic types, and also led to technological change. For instance, political and economic events have decreased access to an organic material locally called *lebu* which is a resin from the *Almaciga* tree (genus Agathis) which Dalupa potters use to coat the interior and exterior of water jars. The shortage of resin has led to a simplification in production so that only the interior of the vessel and the exterior to the shoulder of the traditional jar are coated with the resin (Stark 1991:199). Stark's study shows that change in a ceramic assemblage, in this case Dalupa, represents a response to a variety of factors (environmental, ecological and political).

Another ethnographic study by Anders Lindahl and Innocent Pikiray of Shona potters in Zimbabwe shows that potters are conservative, and that the way a pottery vessel is built is very static with all potters using the same pulling/paddle and anvil technique. Archaeological records of pots from Great Zimbabwe tradition sites, such as Zvongombe show that a major change in manufacturing methods took place between the early and late Iron Age in Great Zimbabwe over 400-500 years. The early Iron Age vessels were all produced by coiling, and the late Iron Age vessels by pulling/paddle and anvil. The late Iron Age technique is very similar to the method used by Shona potters today. Lindahl and Pikiray (2010) argue that the cultural implications of such a production change must have been significant and from a technological perspective there are definite advantages in using the pulling/paddle and anvil technique over coiling. The coiling technique gives a very limited contact zone between the coils that run more or less diagonal across the vessel wall creating weak spots where physical or thermal tension during firing and use can cause the vessel to crack. The coiling method with only slight diagonal to curved contact zones most often leads to thick vessel walls and by extension, heavy pots as in the case of those recovered at Zvongombe. By using the paddle and anvil technique, it is easier to produce thin-walled vessels and a lighter pot. From a potter's perspective, a change towards such a technique has advantages such as the use of less clay to make a pot, which decreases the work required in digging and transporting the clay. Manufacturing by paddle and anvil technique is also much faster than coiling, needing only around half the time for a skilled potter to complete a vessel (Lindahl and Pikiray 2010:19; Lindahl, personal communication Nov. 2015).

Both of the studies summarised above provide some understanding of why changes in ceramic production occur alongside non-technical factors such as the general social, political and cultural milieu, which are difficult to identify in the archaeological record (Kranzberg 1986; Lechtman 1984 in Stark 1991:211).

The fact that there are differences, not only in vessel forms, but in decorative motifs, firing and manufacturing technologies, likely indicates that Austronesians interacted with populations already living in different areas of ISEA. People may have been open to accepting and adopting the new ceramic technology, just as they, in some instances, probably denied or rejected certain aspects of the Austronesian lifestyle, e.g. agriculture (as is also seen with Cardial Ware in Europe).

The rapid Austronesian population spread was likely facilitated by pre-existing networks of populations living in ISEA and the Pacific. Recently Pawlik *et al.* (2015) have argued that a *Tridacna* adze from the central Philippines provides support for inter-island voyaging and down-the-line contact between Island Melanesia and the Philippines from the mid-Holocene, and possibly earlier. Similar pre-pottery contacts have been argued by Denham (2013; 2011) and Denham and Donohue (2009) for the introduction of New Guinea derived plants in ISEA, and also for human dispersed animals such as *Phalanger orientalis* from New Guinea to east Timor and the Moluccas (Flannery *et al.*1996; Glover 1986).

The timing of pottery adoption varied slightly across the region as different parts of the network adopted knowledge at different times. The new technology of pottery making, I suggest, was differentially incorporated into communities and was probably adjusted to fit with their needs, ideology and perhaps religious beliefs. There are no obvious signs of trade in pottery during this period as proposed in Solheim's model, but very little research has been carried out on the composition of prehistoric ceramics in ISEA (Swete Kelly and Winter 2015). A scenario where different populations in ISEA took up pottery-making, would likely result in ceramics that retain broad similarities with those from a source, these being red-slipped surfaces, similarity in vessel forms and some decorative elements. The affinities between different assemblages would then reflect a shared influence, rather than complete transmission of the 'homeland' ceramic repertoire.

10.11. Implications for Indo-Pacific archaeology

The present study of pottery from Unai Bapot and other Neolithic sites in ISEA and the Pacific has clearly demonstrated that there is significant variation among early pottery assemblages (see Chapter 9). It has also demonstrated that ceramic analyses have a crucial role in testing and creating new hypotheses of migration in the Indo-Pacific. Considering the importance given to red-slip ceramics in ISEA and the Pacific, it is surprising that so few attempts have been made to understand the oldest pottery assemblages of the region. Most ceramic studies are general rather than specific and the assertion of a significant prehistoric migration is built on relatively modest archaeological data. It has sometimes been the case that if pottery from a site in ISEA has a red surface then it is used to infer and model human migration, and the substantial differences between pottery assemblages and their historical meaning have been neglected as a result.

Spriggs, for instance, has argued that: "A 4000 BP pottery assemblage in Luzon may not be directly comparable to a 3500 BP assemblage in Sulawesi or the Marianas, or a 3000 BP assemblage in Sabah. When they are very similar that is all to the good, but if they are not then we should not be too surprised. There is a desperate need for closed assemblages of comparable ages as the comparison sample in ISEA — as we have with Lapita. Such sites are extremely scarce in this region at present" (Spriggs 2011a:521).

I agree with Spriggs that we need more ceramic assemblages and better radiocarbon dating of sites to establish contemporaneity, but I would argue that there *are* substantial ceramics assemblages already excavated from various sites in ISEA and the Pacific that have not been thoroughly analysed, and much knowledge can be gained from these. Petrographic studies and manufacturing studies should be added to ordinary pottery studies of vessel form, body sherd thickness and so on. Only when this is done can we truly say something about the relationships of ceramics from different regions and island groups.

It has recently been suggested that the highly decorated pottery belonging to the Lapita Cultural Complex in the Bismarck Archipelago has its ultimate origins in the northern Philippines, and was further developed by migrants from Luzon who were the first settlers in the Mariana Islands. These people after colonising the Marianas then moved south into the Bismarck Archipelago and influenced Lapita groups. (Carson *et al.* 2013).

In the light of new dating evidence from Unai Bapot and the results of the manufacturing study, this hypothesis appears unlikely. Decorated ceramics in the earliest assemblages in the Mariana Islands, as in Nagsabaran, are rare, with less than 1% of any early ceramic assemblage decorated (Hung *et al.* 2011). This is in contrast to the high proportion of decorated sherds present in early Lapita sites. Also, the variety of vessel forms differs significantly among sites from a relatively large amount of distinct vessel types in the Nagsabaran assemblages to only a few in the Mariana Islands, to a large variety of vessel forms in Lapita sites (Carson *et al.* 2013).

The differences in manufacturing technology and the fact that early Mariana ceramic assemblages lack most of the reported vessel forms found at Nagsabaran has been explained as: "localised modifications expected in a classic founder-effect scenario" (Hung *et al.* 2012:911). When the opposite is noted, as in Lapita where a larger variety of decoration and vessel forms are found, the same authors write: "Founder-effect transformation must be recognised as more than a monotonic diminishing of sub-sets, with each successive offspring group progressively further separated from its larger parent population. Along with the bottle-neck loss of certain ancestral traits, each sub-set gains new characters of integrative or innovated traits. This outcome is most noticeable in the case of Lapita, wherein a rather limited inherited core decorative system was impressively elaborated". (Carson *et al.* 2013:30).

This argument appears doubtful as the model supposes that society and forms of material culture, in this case pottery, were largely reinvented each time a new area was colonised. It seems unlikely that the new colonists in the Mariana Islands immediately started to produce a new version of their ceramics, changing their manufacturing methods and vessel forms as soon they reached a new landmass. Most likely the people who reached the Marianas explored the new environment and found the natural resources that they were familiar with from previous experience. I suggest that the difference between Nagsabaran ceramics and the oldest pottery from the early Mariana Islands can be explained without resorting to the 'Founder Effect': the ceramic data indicate that the Mariana Islands were not colonised directly from northern Luzon. Interaction likely took place between dispersing and indigenous groups at various places in ISEA after ceramic-making groups left Luzon, and this is the main cause of ceramic variation found between Nagsabaran and other sites such as Unai Bapot. As mentioned previously it seems highly unlikely that already existing populations in ISEA were just passive receivers who adopted a new technology without having any input of their own.

The Founder-Effect explanation becomes even more *ad hoc* when trying to explain Lapita as an elaborated decorative system that developed from Mariana Islands decorated ceramics, where 1% or even less of the excavated sherds were decorated. The very earliest Lapita ceramic assemblages from the Bismarck Archipelago are dominated by open bowls supported by pedestals or ring-feet (vessel types not yet found in the Mariana Islands), with large portions of the vessel decorated (Kirch 2000). The Lapita design and ceramic system cannot be explained as an elaboration since current evidence suggests it was a fully formed system when it arrived/began in the Bismarck Archipelago.

The ceramic analyses conducted in this thesis show that the most similar ceramics in ISEA and the Mariana Islands from the perspective of manufacturing, temper and vessel forms derive from a belt in ISEA with a starting point in the Talaud Islands in the north to the Moluccas islands including Kayo Island, and Pulau Ay, Banda Islands, through to East Timor in the very south (see Figures 85-86, Chapter 9.4). Interestingly, this is exactly the same area where it has been suggested that there was an early connection with New Guinea and that human-mediated animal translocation took place in the early Holocene.

In voyaging terms, the best routes to western Micronesia lie in the seaway between Mindanao and the Bird's Head of New Guinea (see Chapter 4: Figure 8). The nearby Halmahera region in the Moluccas has previously been suggested as the Lapita 'homeland' (Bellwood and Koon 1989; Irwin 1992). One site of special interest is Uattamdi rockshelter on Kayo Island (see Figure 83). Finds of ceramics include thin (average body sherd thickness 3-4 mm), coral and volcanic sand tempered, red-slipped pottery from relatively small (~20 cm/diameter) globular vessels with restricted rims and open bowls. Almost all of the ceramics found were plain with a small number of incised sherds, and some notched and scalloped rim sherds (Irwin *et al.*1999). The red-slipped sherds were found together with ground stone and limestone adzes, shell disc beads, bracelets, spoons/scarpers, knives and lot of worked pearl shell.

Uattamdi's lowest cultural layer is dated to 3440±110 BP (ANU 7776) on a small bivalve found in a hearth (Bellwood 1992:54-58; Irwin *et al.* 1999). Reconstructed vessels from Uattamdi (Bellwood 1992:56) have a close affinity with Lapita vessel forms - Patrick Kirch describes them as virtually identical to vessel forms at Lapita sites like Talepakemalai and Etakosarai in Mussau (Kirch 1997:50). The Uattamdi globular vessels with restricted rims and open bowls vessels also have close affinity with early Mariana Islands vessels, which contrast with the rather sharp everted concave rims as found in Chaolaiqiao, Taiwan, in the Batanes Islands, at Nagsabaran, Philippines, or those from Minanga Sipakko and Kamassi in Karama Valley, Sulawesi (see Figure 83; Anggraeni *et al.* 2014:745).

I suggest that the Austronesian expansion into ISEA took different routes and that this is seen in different ceramic traditions, one western with the Karama Valley sites and one eastern with sites from Talaud down to east Timor and out to the Pacific. Further research might well show an increasing number of shared pottery traits. Interestingly, the pottery from Bukit Tengorak in Sabah, Borneo, that geographically should belong to a western tradition, seems to show closer affinities with ceramics in the proposed 'Talaud' belt and with Pacific ceramics, as suggested by Anggraeni *et al.* (2014).

Bukit Tengorak is the only site with firm archaeological evidence of an early connection between Island Southeast Asia and Near Oceania/Bismarck Archipelago: obsidian artefacts sourced to Talasea (Kutau/Bao, West New Britain) were found in Neolithic layers at Bukit Tengorak, with the earliest dated to 3315-2951 cal BP and 3186-2892 cal BP and continuing to at least 2968-2463 cal BP (Spriggs *et al.* 2011; Chia, 2003).

Figure 88 illustrates this connection and other geographical relationships between Pre-Neolithic and Neolithic sites.

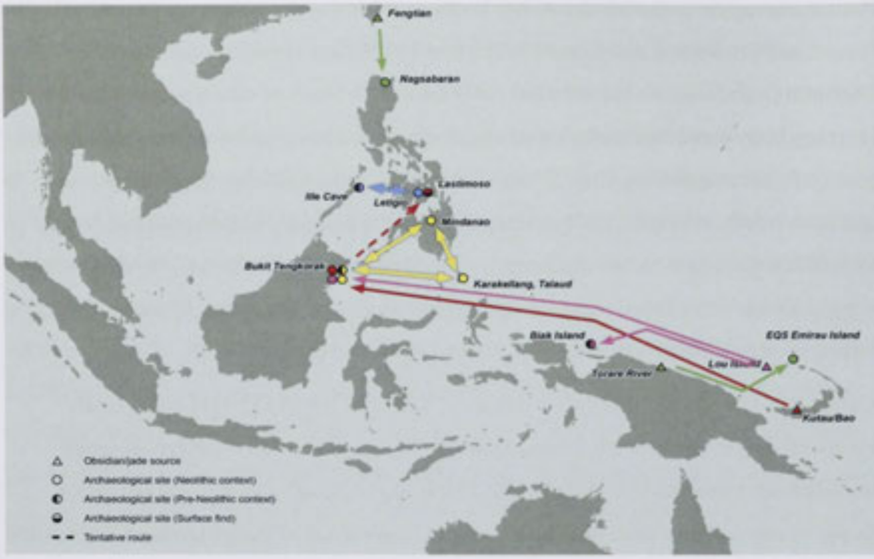

Figure 88. Map of interactions in ISEA and the Pacific in the Pre-Neolithic and Neolithic.

Pre-Neolithic finds of obsidian at Bukit Tengorak, dated to 6280-5940 cal BP, match the age of samples from the Talaud Islands (Spriggs *et al*. 2011; Chia, 2003:57). This might indicate an old connection between Talaud and Sabah, Borneo, which could explain why the Bukit ceramics in the later Neolithic period are more similar to the Leang Tuwo Mane'e (Talaud) ceramics than to the closer Karama Valley sites.

Some of the obsidian from Bukit Tengorak is from a source approximately 3500 kilometres away in the Bismarck Archipelago which illuminates a remarkable case of unambiguous two-way interaction (Bellwood 2011; 1989; Kirch 1997). This trade route might represent an early interaction sphere and migration path out to the Pacific from south of the Philippines.

This thesis has shown that colonisation of the Mariana Islands was likely from south of Luzon. With a new, younger chronology for Unai Bapot and the Mariana Islands, sites such as Leang Tuwo Mane'e and Uattamdi can once again be included in the discussion of a possible homeland for voyages to islands in Remote Oceania. Pottery from these sites has been suggested to have a close relationship with Lapita ceramics (Kirch 1997), but Uattamdi has been considered too young to be ancestral. The ceramic analyses carried out here also point to this area as a possible homeland for the colonisers of the Marianas, although more work at sites such as Uattamdi and elsewhere in the Moluccas needs to be done to support the hypothesis.

A date of 3200-3100 BP for the colonisation of the Marianas proposed here is 600-400 years younger than that proposed by some researchers (Hung *et al.* 2011 and Carson 2014), but is plausible in terms of maritime technology. Winter *et al*. (2012) questioned if early sailing knowledge and maritime technology was developed enough to make extraordinarily long voyages at the very beginning of the Austronesian expansion. The answer is clearly no if people reached the Marianas much later. It has also been argued in this thesis that a colonisation hiatus in western Polynesia for two millennia before the occupation of east Polynesia is curious if Pacific colonisers were able to sail vast distances two millennia earlier, as suggested by the early settlement hypothesis for the Marianas.

Therefore it seems likely that marine technology and knowledge of sailing developed over four to six centuries in the archipelagos of ISEA, and that during this time, Austronesian sailors (and also perhaps non-Austronesian groups) developed boats and learned how to make substantial open ocean voyages. By around 3200-3000 cal BP, an improved maritime capacity looks probable with people leaving ISEA to colonise new island groups like the Mariana Islands, the Bismarck Archipelago and Palau.

A starting point for Marianas colonisation in the Moluccas or Halmahera area as suggested here, is also supported by studies of prehistoric voyaging (Fitzpatrick and Gallaghan 2013). The Mariana Islands could have been reached by using Palau and Yap as stepping stones, as suggested by Irwin (1992:117), although archaeological and linguistic data so far offer no support for this.

The colonisation of the Bismarck Archipelago is a different story. It could have been reached by sailing along the coast of New Guinea from Indonesia, not losing sight of land at any point until the archipelago was reached. The further Lapita expansion into Remote Oceania contains more large islands between the Bismarcks and Samoa than exist in the entirety of east Polynesia, so island geography and voyaging distances are probably what caused a halt in Lapita expansion. The Lapita people likely did not have adequate vessels to colonise areas beyond Tonga and Samoa.

This is probably true for the Mariana Island settlers as well: they had stretched their limits to reach the Marianas as is suggested by the absence of rats and all other domesticated animal. From about 1000 cal BP there are indications that the Marianas were in contact with ISEA from the use of megalithic *latte* stones and the arrival of rats and possibly rice in the archaeological record. Future work incorporating manufacturing and stylistic data from ceramic assemblages will help to clarify the early and late prehistory of population movements in ISEA and the Pacific, including migration routes, and the process of cultural contact and technological transmission, among other issues.

10.12. Concluding remarks

Establishing colonisation chronologies and migration routes are important issues in archaeology, and the research reported here has focussed on the Austronesian expansion in Island Southeast Asia and the Pacific Ocean. The main aim has been to establish the timing and nature of human arrival in the Mariana Islands, including the migration route.

Establishing the antiquity of human colonisation in a previously uninhabited island group should be a relatively straightforward matter requiring, simply, the identification and radiocarbon dating of the oldest cultural deposits. This work has shown that establishing the age of colonisation is not necessarily simple (as many other archaeologists working on islands have also found). Although many of the archaeological sites reported in this thesis probably belong to the colonisation phase in the Mariana Islands, their chronologies are ambiguous and some sites may be younger than has been assumed. One implication of this is that researchers in archaeology, as well as in historical linguistics and genetics, may have used inaccurate chronological data to assemble migration models.

In addition, early ceramic assemblages which only have a generic similarity with one another have been used to identify the origin place of the first settlers to occupy the islands of Remote Oceania. A younger chronology for the Mariana Islands, as suggested here, massively expands the potential homeland area, as pottery-producing people probably occupied almost all of ISEA and possibly coastal areas of New Guinea by ~3200-3000 cal BP.

Rather than focusing on decorative elements, the present study has approached ceramics from a different angle and targeted the pottery production sequence in conjunction with an analysis of stylistic traits. Detailed analyses of manufacturing techniques and sherd mineralogy provide a new and useful method to examine maritime migration and to assess the cultural affinities of colonists with a particular migration source. The method used has a potentially wide use in tracking spatial and temporal patterns of population movement to understand Austronesian movement and interaction in ISEA, as well as within different parts of the Lapita culture distribution, where variation in pottery production has not been studied in depth.

Such work could also play an important role in understanding pottery development in Papua New Guinea. There, in almost all ethnographic reports on contemporary coastal sites occupied by Austronesian-speaking people, it is the women who produce pottery by paddle and anvil, whereas at inland sites occupied by Papuan language-speakers, the majority of potters are men who produce pottery by coiling (May and Tuckson 2000; Pétrequin and Pétrequin 2006). Future work on ceramic assemblages might investigate how and when the gender divide in pottery production began.

Studies of the Neolithic expansion in ISEA and the Pacific are relatively young compared to similar studies of the Neolithic in Europe (Montelius 1884: Childe 1925, 1936). Yet, regional archaeologists in the Indo-Pacific have adopted many of the same arguments and the debate follows a similar trajectory (Swete Kelly 2015b:3). Considering the short time frame proposed for the spread of agriculture and red-slipped ceramics into ISEA and the Pacific, from northern Luzon c. 3700 cal. BP, the Mariana Islands 3500 cal. BP, and to the Bismarck Archipelago at 3300 cal. BP (Bellwood 2011; Carson *et al*. 2013), it is curious that early ceramics from sites in ISEA, the Mariana Islands and the Bismarck Archipelago do not display greater similarity. This study has shown that there are significant differences among the early ceramic assemblages that often are referred to as belonging to a coherent and easily recognizable Austronesian red-slipped ceramic tradition.

The opposite, however, appears to be the case in Europe where distinct ceramic traditions are present. The Funnel Beaker culture (6300-4800 cal BP) occurs from north-central Europe to southern Scandinavia and in this area the pottery tradition can be characterised as homogenous while the different Linearbandkeramik-tradition in Eastern and Central Europe c. 5500 -4500 cal. BP is also found over a large area (Gill

2003; Lindahl, personal communication 2015). Both ISEA and large parts of Europe were previously inhabited before new pottery traditions arrived and we know little about the social and technological mechanisms that affect ceramic production and style. Future work on establishing the age of early pottery sites in ISEA combined with detailed research on pottery assemblages from ISEA and the Pacific will help us to determine the existence (or not) of a widespread cultural, ethnic and biological community and "Austronesian Red-Slipped Ceramic Culture".

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Appendix 1: Ceramics

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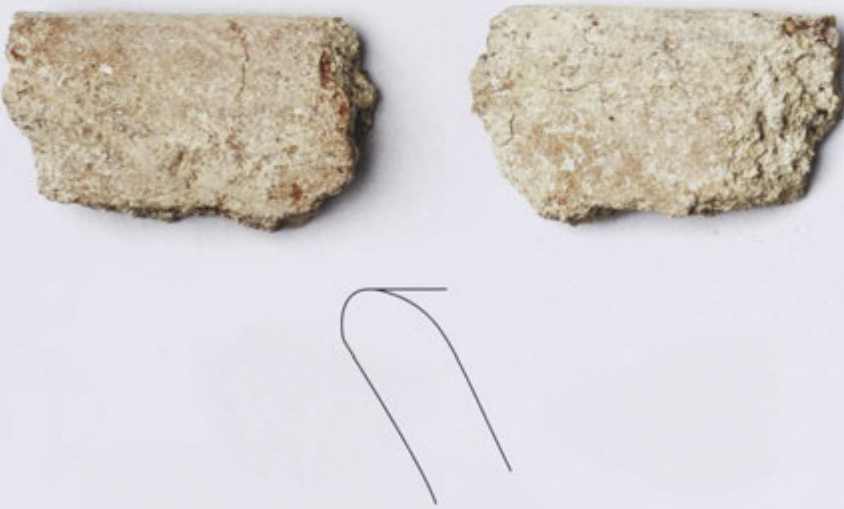

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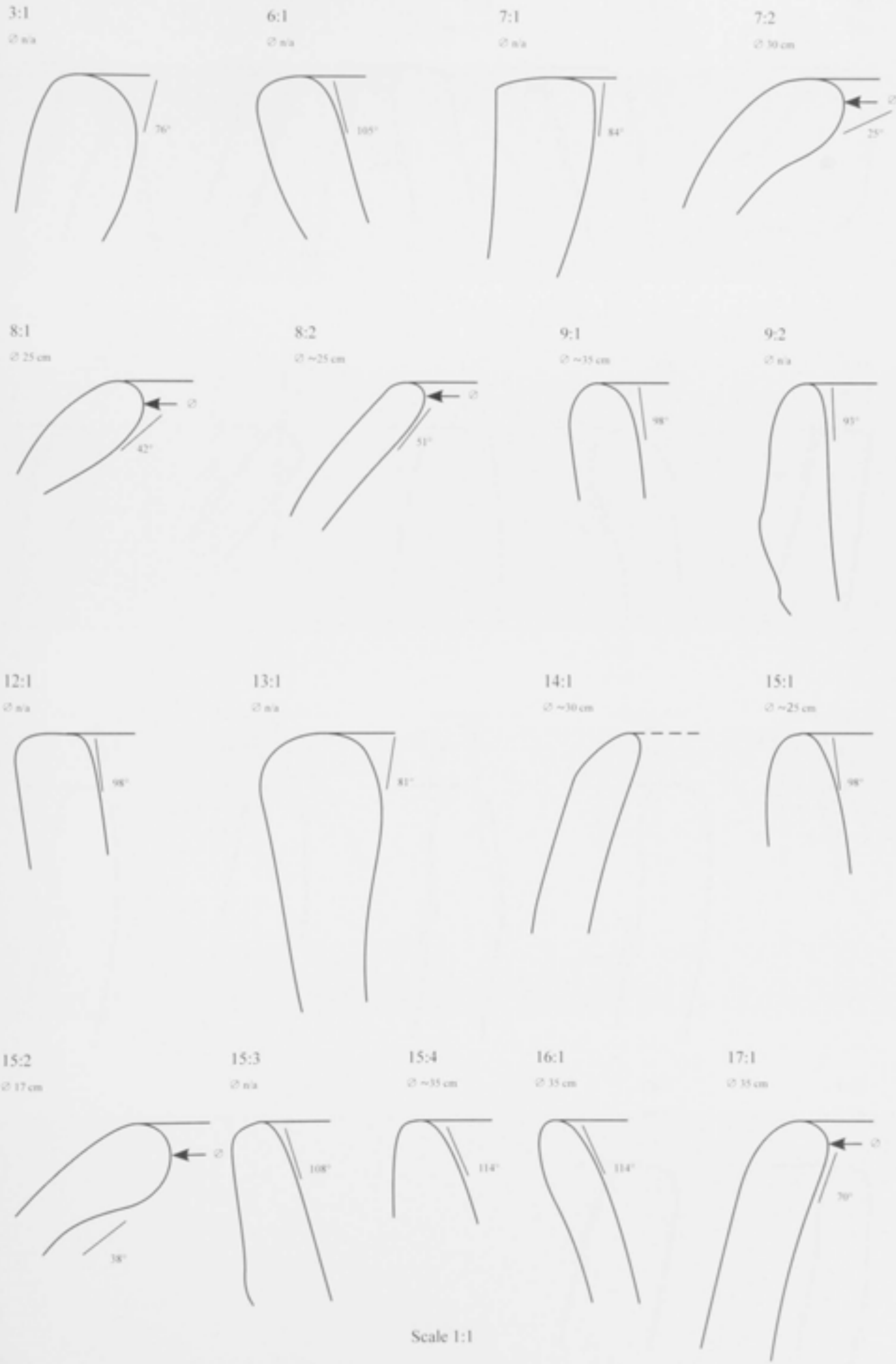
CERAMICS — RIM SHERDS



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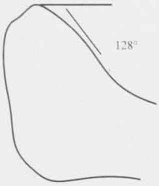
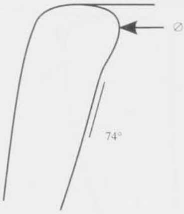
18:1

∅ n/a



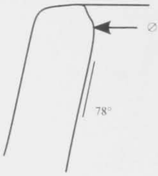
18:2

∅ 35 cm



18:3

∅ ~35 cm



21:1

∅ n/a

22:1

∅ ~20 cm

22:2

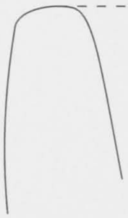
∅ ~40 cm

26:1

∅ ~30 cm

28:1

∅ n/a



28:2

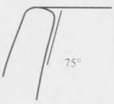
∅ n/a

33:1

∅ 21 cm

37:1

∅ n/a

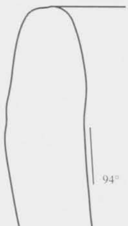


38:1

∅ ~27 cm

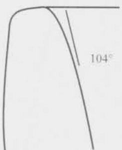
38:2

∅ ~30 cm



39:1

∅ ~40 cm



42:1

∅ n/a

43:1

∅ ~30 cm

44:1

∅ n/a

Scale 1:1

46:1
∅ n/a

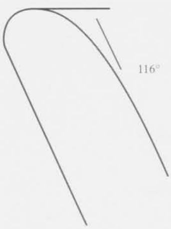

47:1
∅ n/a


47:2
∅ ~30 cm


48:1
∅ ~25 cm


49:1
∅ 15 cm


49:2
∅ n/a


51:1
∅ n/a


51:2
∅ n/a


51:3
∅ n/a


53:1
∅ n/a


Scale 1:1

55:1

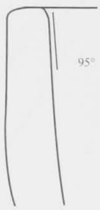
∅ n/a

55:2

∅ n/a

56:1

∅ n/a

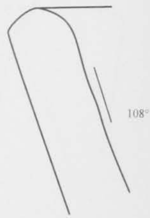


57:1

∅ 25 cm

57:2

∅ n/a



57:3

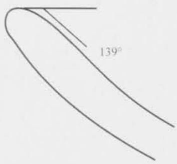
∅ n/a

57:4

∅ n/a

58:1

∅ ~25 cm



59:1

∅ ~30 cm

59:2

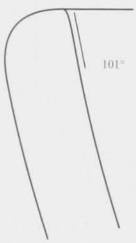
∅ ~35 cm

59:3

∅ n/a

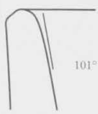
61:1

∅ n/a



63:1

∅ ~30 cm



Scale 1:1

64:1

∅ ~22 cm

64:2

∅ ~25 cm

67:1

∅ >35 cm

67:2

∅ n/a

68:1

∅ n/a

68:2

∅ n/a

68:3

∅ n/a

68:4

∅ n/a

70:1

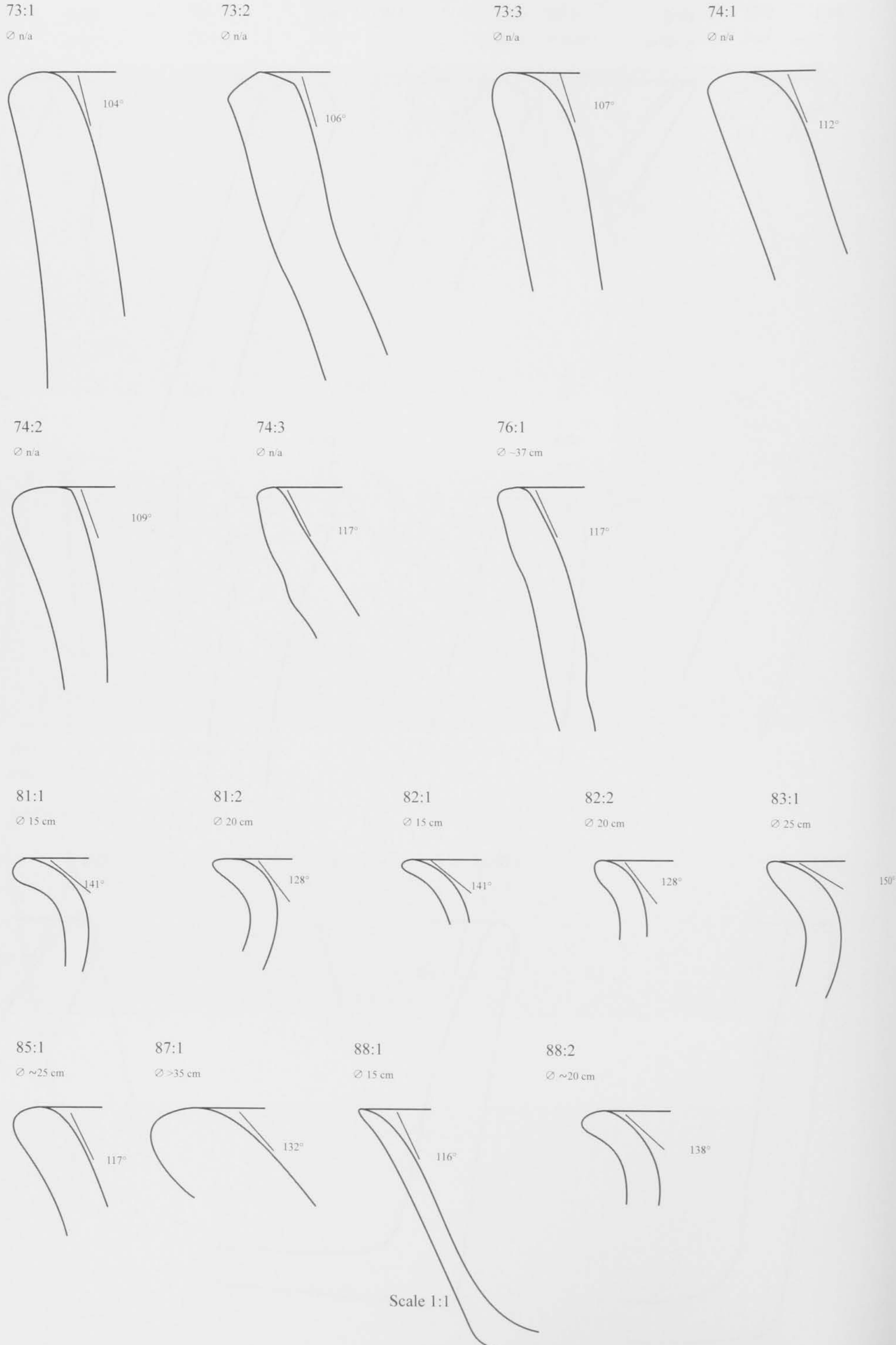
∅ n/a

70:2

∅ n/a

71:1

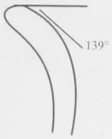
∅ ~23 cm


73:1
∅ n/a
104°
73:2
∅ n/a
106°
73:3
∅ n/a
107°
74:1
∅ n/a
112°
74:2
∅ n/a
109°
74:3
∅ n/a
117°
76:1
∅ ~37 cm
117°
81:1
∅ 15 cm
141°
81:2
∅ 20 cm
128°
82:1
∅ 15 cm
141°
82:2
∅ 20 cm
128°
83:1
∅ 25 cm
150°
85:1
∅ ~25 cm
117°
87:1
∅ >35 cm
132°
88:1
∅ 15 cm
116°
88:2
∅ ~20 cm
138°

Scale 1:1

89:1

∅ 12 cm



89:2

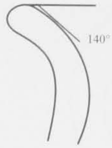
∅ 17 cm

90:1

∅ 18 cm

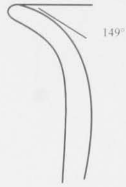
90:2

∅ n/a



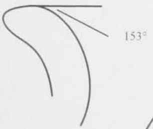
92:1

∅ n/a



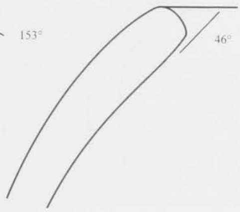
92:2

∅ n/a



92:3

∅ n/a



93:1

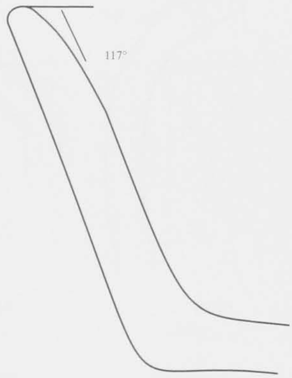
∅ ~25 cm

93:2

∅ ~25 cm

93:3

∅ ~45 cm

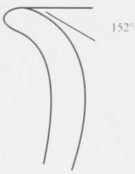


94:1

∅ 15 cm

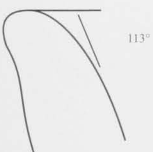
94:2

∅ 18 cm



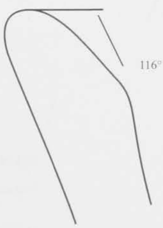
96:1

∅ >40 cm



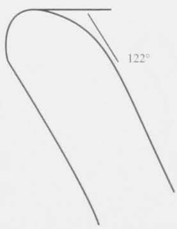
96:2

∅ n/a



96:3

∅ n/a



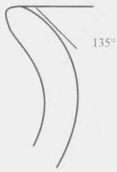
96:4

∅ n/a

Scale 1:1

97:1
∅ 15 cm

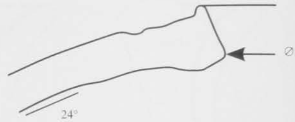
100:1
∅ 17 cm



100:2
∅ 20 cm

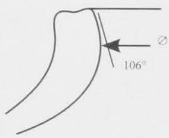
100:3
∅ ~25 cm

100:4
∅ 30 cm



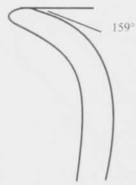
100:5
∅ 34 cm

101:1
∅ 15 cm



102:1
∅ 19 cm

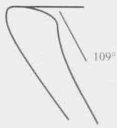
102:2
∅ 20 cm



102:3
∅ 25 cm

102:4
∅ 25 cm

103:1
∅ n/a



104:1
∅ n/a

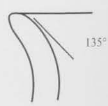
105:1
∅ 15 cm

105:2
∅ 18 cm

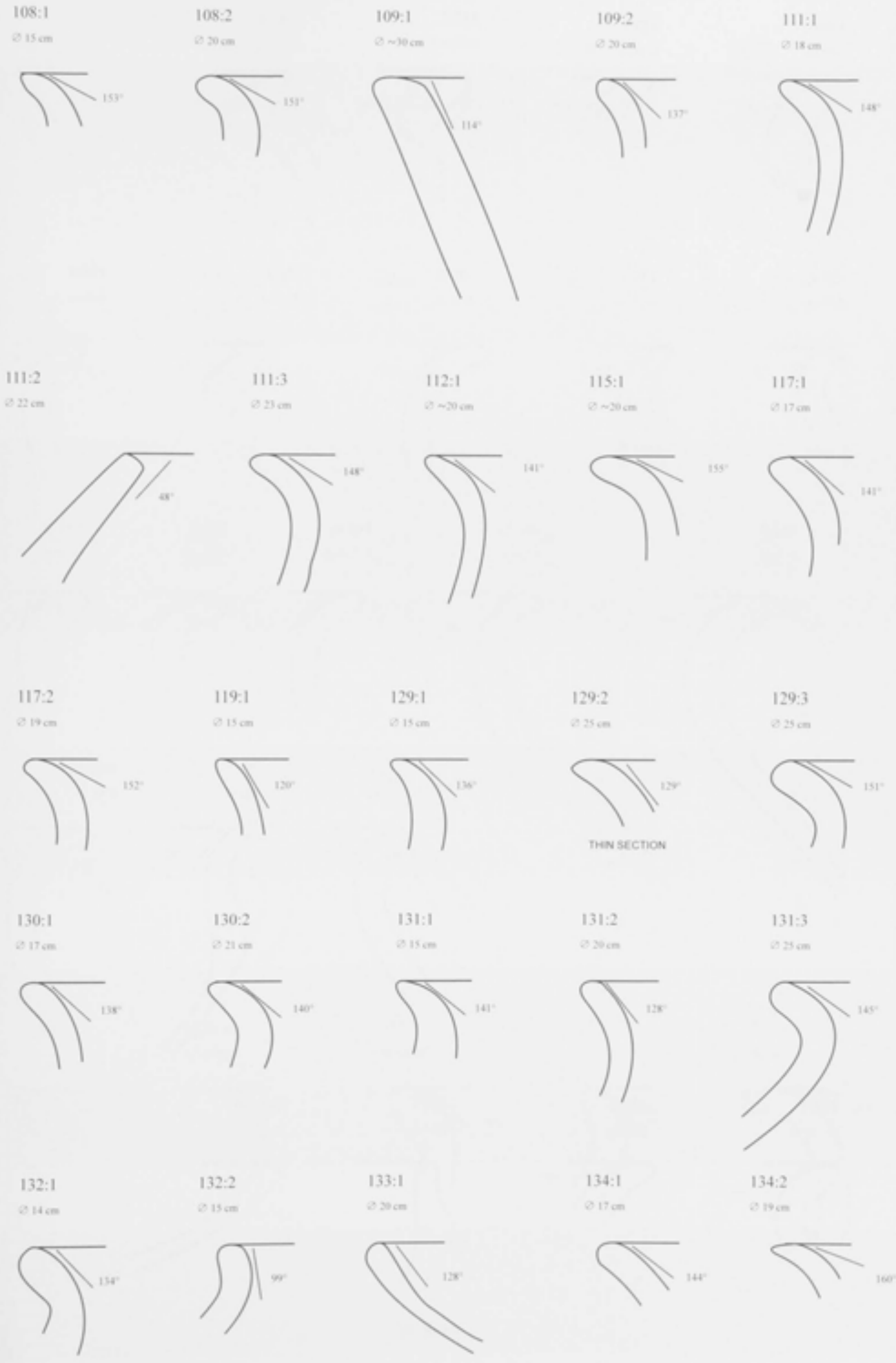
105:3
∅ 20 cm

105:4
∅ 22 cm

107:1
∅ 17 cm



Scale 1:1


108:1
∅ 15 cm
153°
108:2
∅ 20 cm
151°
109:1
∅ ~30 cm
114°
109:2
∅ 20 cm
137°
111:1
∅ 18 cm
148°
111:2
∅ 22 cm
48°
111:3
∅ 23 cm
148°
112:1
∅ ~20 cm
141°
115:1
∅ ~20 cm
155°
117:1
∅ 17 cm
141°
117:2
∅ 19 cm
152°
119:1
∅ 15 cm
120°
129:1
∅ 15 cm
136°
129:2
∅ 25 cm
129°
THIN SECTION
129:3
∅ 25 cm
151°
130:1
∅ 17 cm
138°
130:2
∅ 21 cm
140°
131:1
∅ 15 cm
141°
131:2
∅ 20 cm
128°
131:3
∅ 25 cm
145°
132:1
∅ 14 cm
134°
132:2
∅ 15 cm
99°
133:1
∅ 20 cm
128°
134:1
∅ 17 cm
144°
134:2
∅ 19 cm
160°

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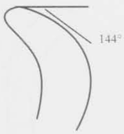
136:1

∅ 25 cm



137:1

∅ 14 cm

137:2

∅ 21 cm

137:3

∅ 20 cm

138:1

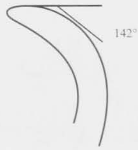
∅ 25 cm

139:1

∅ 13 cm

139:2

∅ 20 cm



139:3

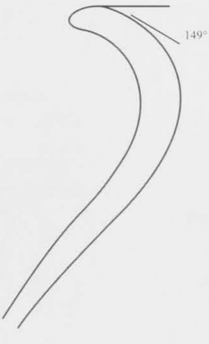
∅ 20 cm

141:1

∅ 18 cm

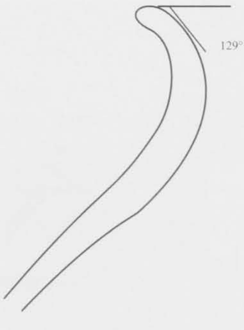
141:2

∅ 15 cm



141:3

∅ 15 cm



141:4

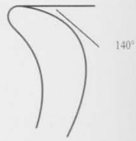
∅ ~20 cm

141:5

∅ 25 cm

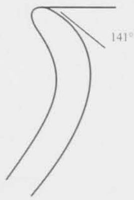
141:6

∅ 30 cm



142:1

∅ 16 cm

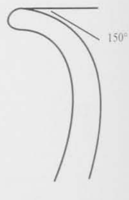


143:1

∅ 18 cm

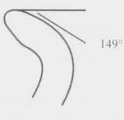
143:2

∅ 18 cm



144:1

∅ ~20 cm



144:2

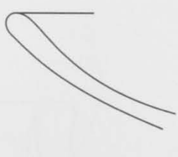
∅ 23 cm

145:1

∅ 20 cm

145:2

∅ 20 cm



Scale 1:1

146:1
∅ 15 cm


146:2
∅ 15 cm


146:3
∅ 17 cm


146:4
∅ 20 cm


146:5
∅ 20 cm


146:6
∅ ~25 cm


147:1
∅ 15 cm


147:2
∅ 19 cm


147:3
∅ ~22 cm


147:4
∅ 23 cm


148:1
∅ 17 cm


148:2
∅ 19 cm


148:3
∅ 20 cm


149:1
∅ 29 cm


150:1
∅ ~20 cm


150:2
∅ n/a


151:1
∅ 11 cm


151:2
∅ 15 cm


151:3
∅ 22 cm


152:1
∅ 10 cm


152:2
∅ ~15 cm


152:3
∅ 20 cm


152:4
∅ ~20 cm

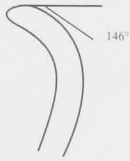

152:5
∅ ~25 cm


152:6
∅ 25 cm


Scale 1:1

BAPOT

152:7
∅ n/a



153:1
∅ 18 cm

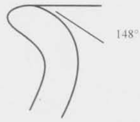
153:2
∅ 18 cm

153:3
∅ ~25 cm

154:1
∅ 15 cm

154:2
∅ 15 cm

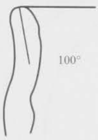
154:3
∅ 20 cm



154:4
∅ 20 cm

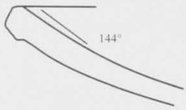
154:5
∅ 23 cm

154:6
∅ n/a



155:1
∅ 25 cm

157:1
∅ 20 cm

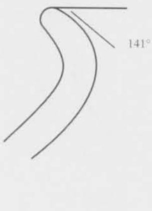


157:2
∅ 25 cm

157:3
∅ 20 cm

157:4
∅ 16 cm

158:1
∅ 18 cm



158:2
∅ 20 cm

158:3
∅ 20 cm

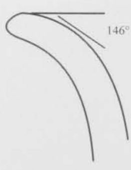
158:4
∅ 20 cm

158:5
∅ 25 cm

158:6
∅ n/a

159:1
∅ 17 cm

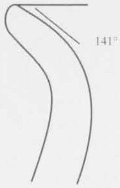
159:2
∅ 18 cm



159:3
∅ 19 cm

159:4
∅ 20 cm

159:5
∅ 23 cm



159:6
∅ 23 cm

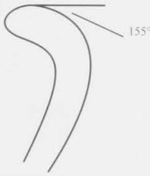
159:7
∅ 28 cm

159:8
∅ ~35 cm

160:1
∅ 18 cm

160:2
∅ 22 cm

160:3
∅ 23 cm

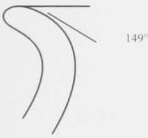


160:4
∅ 23 cm

160:5
∅ 25 cm

160:6
∅ n/a

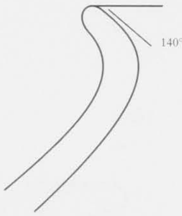
156:1
∅ 14 cm



156:2
∅ ~20 cm

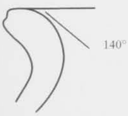
156:3
∅ 20 cm

156:4
∅ 21 cm



162:1
∅ 10 cm

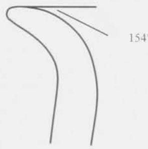
163:1
∅ 15 cm



163:2
∅ 15 cm

163:3
∅ 15 cm

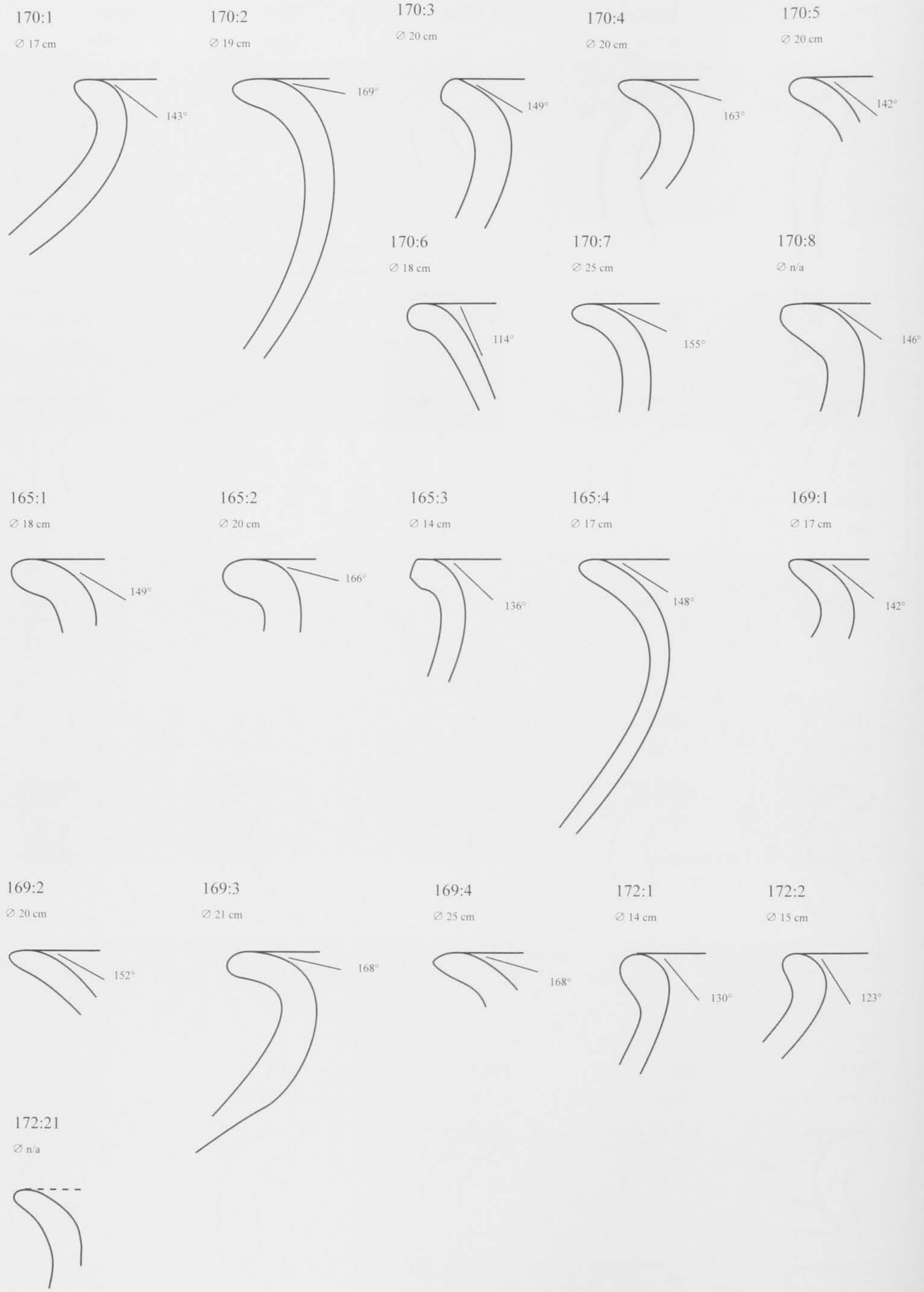
163:4
∅ 20 cm



163:5
∅ 25 cm

Scale 1:1

BAPOT



Scale 1:1

CERAMICS — RIM SHERDS

Scale 1:1

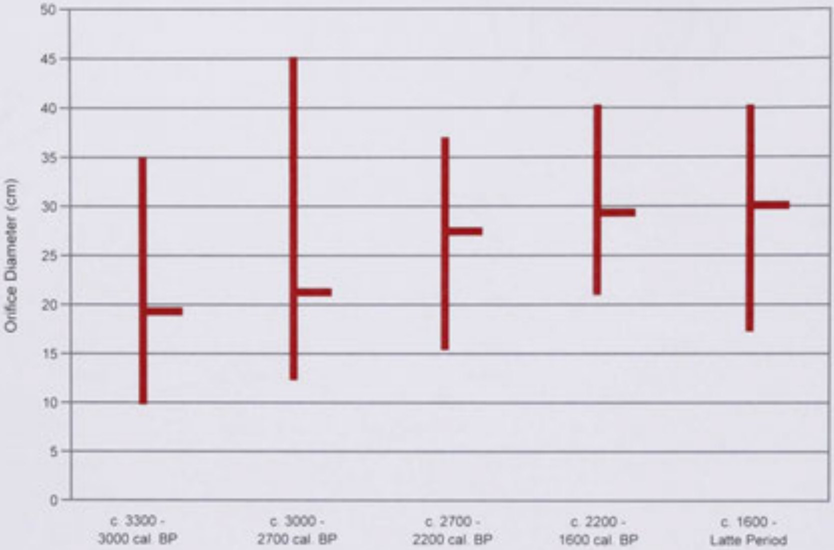


Fig 1-1. Change in mean orifice diameter.

Scale 1:1

Reconstructions

47:2

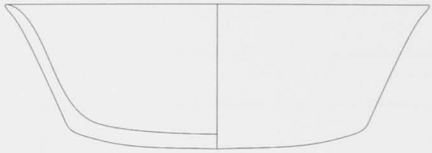
∅ ~30 cm

64:2

∅ 25 cm

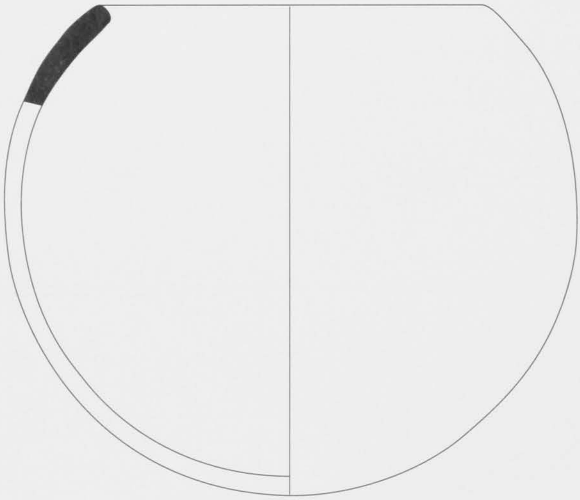
88:1

∅ 15 cm



92:3

∅ n/a



93:3

∅ ~45 cm

Scale 1:4

Scale 1:2

100:5

∅ 34 cm

102:3

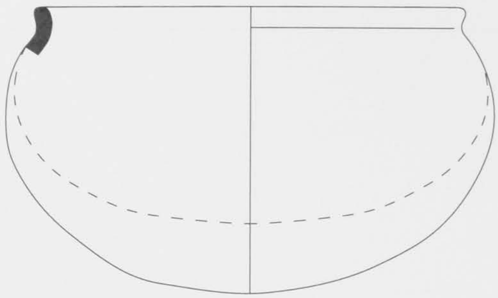
∅ 25 cm

109:1

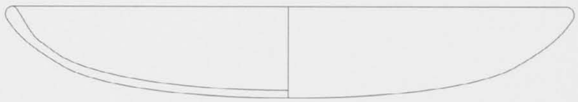
∅ 30 cm

Scale 1:2

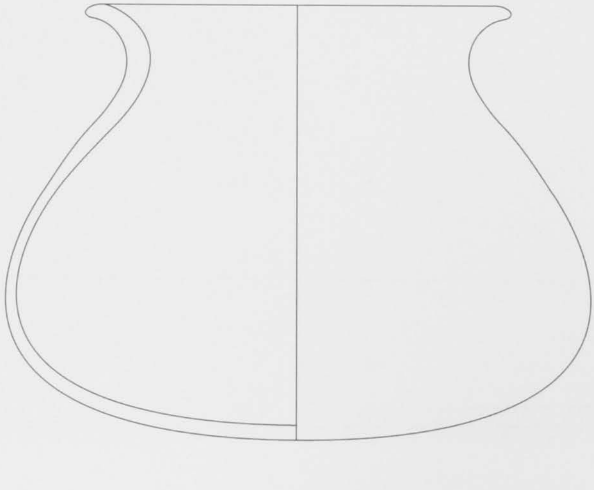
132:2
∅ 15 cm



133
∅ 20 cm



141:2
∅ 15 cm



Scale 1:2

143:1
∅ 18 cm

145:1
∅ 20 cm

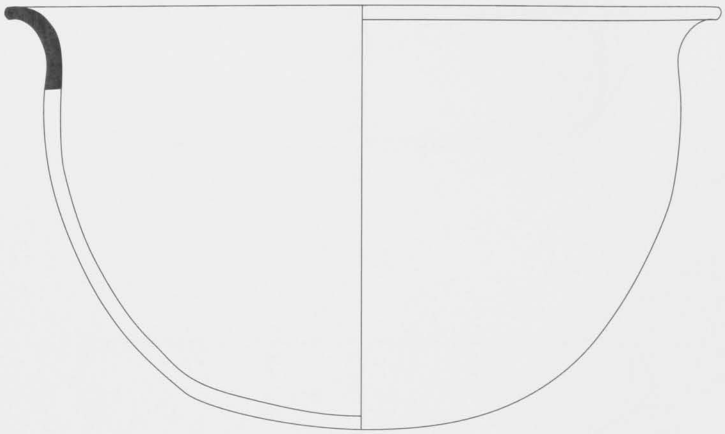
145:2
∅ 20 cm

146:5
∅ 20 cm

Scale 1:2

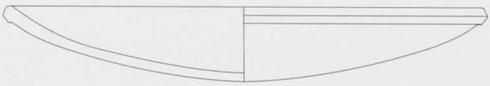
152:6

∅ 25 cm



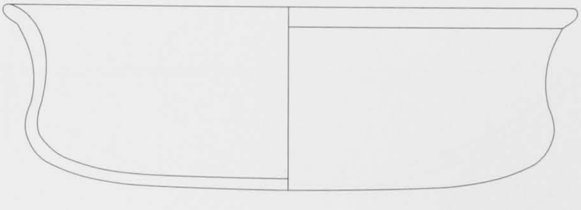
157:1

∅ 17 cm



159:4

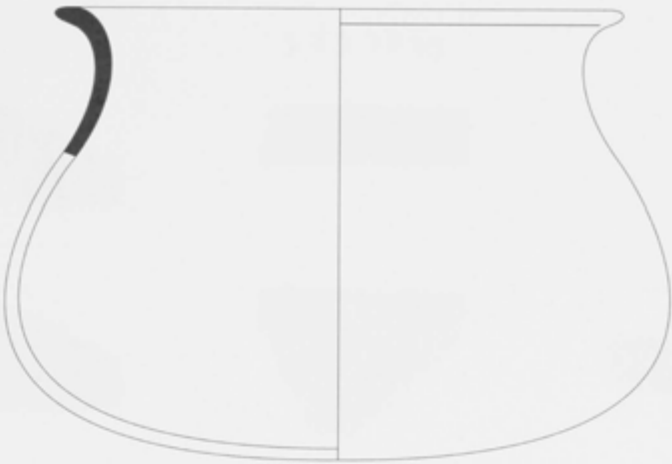
∅ 20 cm



Scale 1:2

163:4
∅ 20 cm

170:2
∅ 10 cm



173:1
∅ 17 cm

Scale 1:2

173:2

∅ 20 cm

Scale 1:2

Decoration

4:1 IN/GR

24:3 PAD

28:3 PAD

50:1 SH IMP

83:2 PUN LI

89:3 PUN

92:4 DS

116:5 IN LI (SR)

126:2 STC

131:10 IN LI (SR)

131:11 IN LI (SR)

142:9 IN LI (SR)

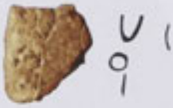
142:10 IN LI (SR)

145:3 IN LI (SR)

145:4 IN LI (SR)

146:14 IN/GR

152:9 IN



153:12 IN LI (SR)

159:18 IN LI (SR)

Scale 1:1

161:1 IN LI (SR)

164:1 IN LI (SR)

167:1 DS (ACH)

170:12 IN LI (SR)

170:13 IN LI (SR)

170:14 IN LI (SR)

Abbreviations

DS:	Dentate stamped	IN/GR:	Incised/Grooved
DS (ACH):	Dentate-stamped (Achuago)	PAD:	Paddle-marked
GR:	Grooved	PUN:	Punctated
IN:	Incised	PUN LI:	Punctated Lime-infilled
IN LI:	Incised Lime-infilled	SH IMP:	Shell Impressed
IN LI (SR):	Incised Lime-infilled (San Roque)	STC:	Stamped circles

Scale 1:1

Table 1-1. List of decorated sherds

Cat. no.	Depth (cm)	Unit	Decoration
4:1	23-35	4	IN/GR
16:3	35-50	7	PAD
24:3	50-65	6	PAD
28:3	65-80	1	PAD
38:3	80-90	2	GR
50:1	90-100	5	SH IMP
83:2	130-140	3	PUN LI
89:3	140-150	9	PUN
92:4	140-150	4	DS
92:7	140-150	4	SH IMP
103:2	150-160	7	IN LI
116:5	170-180	4	IN LI (SR)
118:1	170-180	6	STC
126:2	180-190	6	STC
131:10	190-200	3	IN LI (SR)
131:11	190-200	3	IN LI (SR)
140:8	200-210	3	IN LI (SR)
140:9	200-210	3	IN LI (SR)
142:9	200-210	5	IN LI (SR)
142:10	200-210	5	IN LI (SR)
145:3	200-210	8	IN LI (SR)
145:4	200-210	8	IN LI (SR)
146:2	210-220	1	STC
146:13	210-220	1	IN LI (SR)
146:14	210-220	1	IN/GR
152:9	210-220	7	IN
153:12	210-220	8	IN LI (SR)
155:5	220-230	2	IN LI (SR)
159:18	220-230	5	IN LI (SR)
161:1	230-240	1	IN LI (SR)
164:1	240-250	1	IN LI (SR)
167:1	250-260	2	DS (ACH)
170:12	230-240	5	IN LI (SR)
170:13	230-240	5	IN LI (SR)
170:14	230-240	5	IN LI (SR)
172:20	240-250	5	PUN
Feature K:10	245-275	–	STC

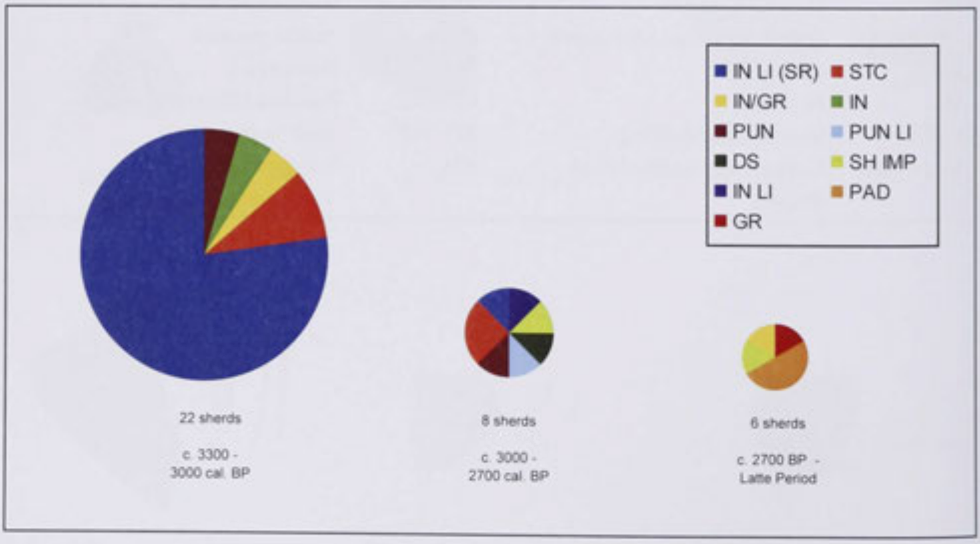


Fig 1-2. Chronological distribution of different types of decoration.

Classification

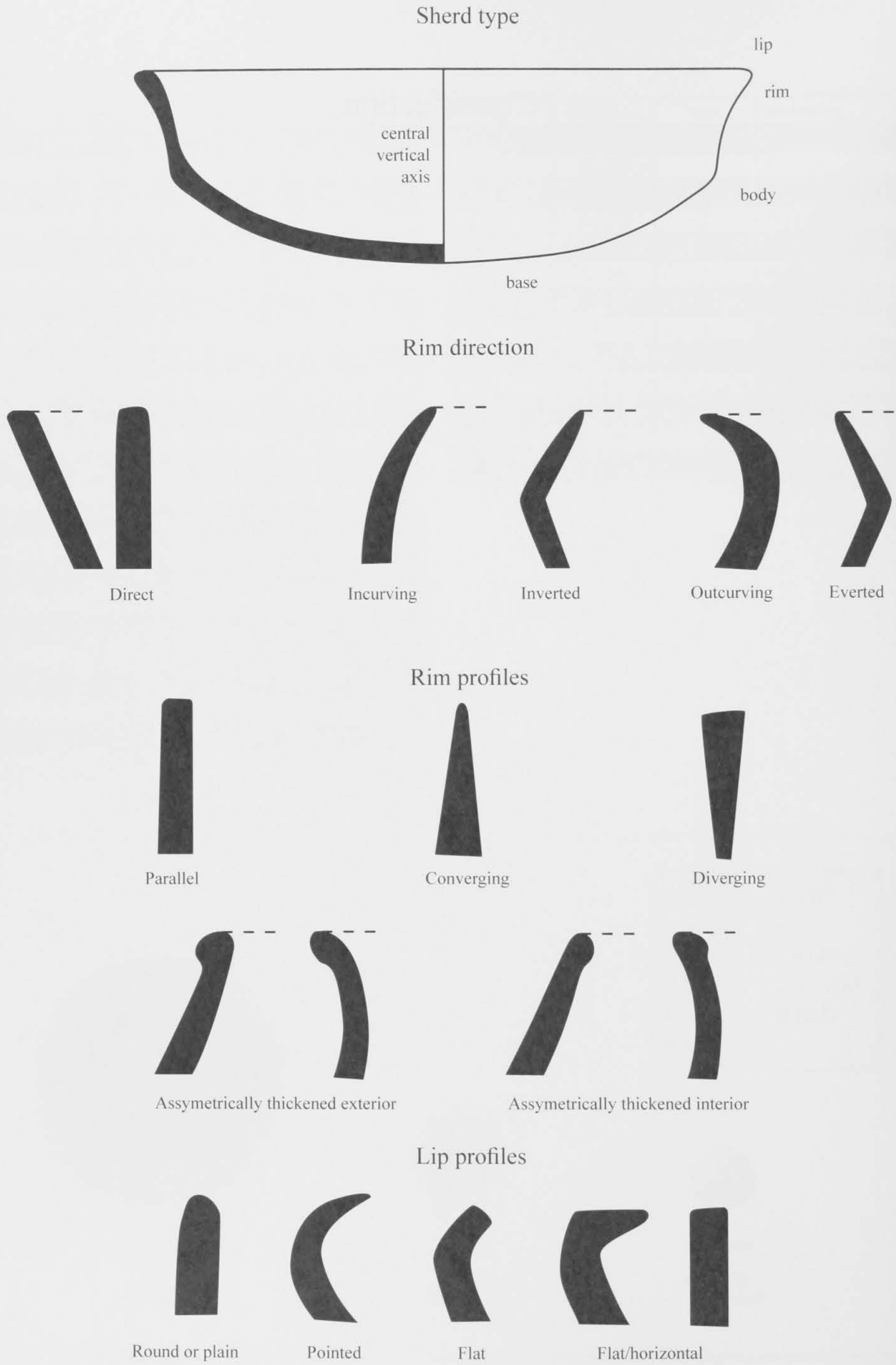
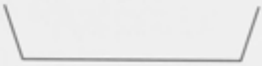


Fig 1-3. Sherd classification attributes (modified after Bedford 2006, p. 75).

D) Direct

Unrestricted vessels with direct vertical or steep rim/wall orientation and varying rim and lip profiles. Mostly parallel or converging rim profile and rounded or flat lip profile.



The direct rim sherds were divided into two sub-groups based on size:

D1: Thin ware (wall thickness 5 – 11 mm).
D2: Thick ware (maximum wall thickness > 11 mm).

B) Bowls

Unrestricted vessels/open shallow bowls with incurving rim direction and varying rim and lip profiles.

The direct rim sherds were divided into two sub-groups based on size:

B1: Thin ware (wall thickness 3 – 5 mm).
B2: Thick ware (wall thickness ≈ 7 mm).

I) Incurving

Restricted vessels with incurving rim direction, varying rim profile and in most cases rounded or flat lip profile.

I1 I2

The direct rim sherds were divided into three sub-groups based on rim angle or wall thickness.

I1: Rim angle ≈ 25 – 50°.
I2: Rim angle ≈ 60 – 80°.
I3: Thick ware (maximum wall thickness > 11 mm).

O) Outcurving

Restricted vessels with outcurving rim direction and varying rim and lip profiles.

O1 O2 O3

O1: Parallel or near parallel rim profile and rounded lip profile.
O2: Gradually converging rim profile and rounded lip profile.
O3: Gradually converging rim profile and pointed lip profile.

Fig 1-4. System of classification.

List of finds

Abbreviations

DS:	Dentate stamped	IN/GR:	Incised/Grooved
DS (ACH):	Dentate-stamped (Achuago)	PAD:	Paddle-marked
GR:	Grooved	PUN:	Punctated
IN:	Incised	PLI:	Punctated Lime-infilled
IN LI:	Incised Lime-infilled	SH IMP:	Shell Impressed
IN LI (SR):	Incised Lime-infilled (San Roque)	STC:	Stamped circles

Cat. no.	Depth (cm)	Unit	T_1 (mm)	T_2 (mm)	Dia. (cm)	Rim dir.	Rim profile	Lip profile	Type	Carina-tion	Decora-tion
1:1	23-35	1	9	9	–	D	–	–	**D1**	–	–
1:2	23-35	1	23	26	–	I	–	–	**I3**	–	–
2:1	23-35	2	7	10	–	D	–	–	**D1**	–	–
2:2	23-35	2	8	11	–	D	–	–	**D1**	–	–
3:1	23-35	3	19	21	–	I	D	R	**I3**	–	–
3:2	23-35	3	11	12	–	I	–	–	**I1**	–	–
4:1	23-35	4	–	–	–	–	–	–	**–**	–	IN/GR
4:2	23-35	4	8	9	–	I	–	–	**I1**	–	–
6:1	23-35	6	12	11	–	D	D	R	**D2**	–	–
6:2	23-35	6	19	16	–	I	–	–	**I3**	–	–
7:1	23-35	7	18	13	–	I	D	FH	**I3**	–	–
7:2	23-35	7	14	11	30	I	D	R	**I3**	–	–
7:3	23-35	7	16	12	–	I			**I3**	–	–
8:1	23-35	8	10	9	25	I	D	R	**I3**	–	–
8:2	23-35	8	8	7	25	I	P	R	**I1**	–	–
9:1	23-35	9	11	12	35	D	P	R	**D2**	–	–
9:2	23-35	9	10	14	–	D	–	R	**D2**	–	–
10:1	35-50	1	16	22	–	I	–	–	**I3**	–	–
10:2	35-50	1	9	7	–	I	–	–	**B2**	–	–
10:3	35-50	1	7	11	–	I	–	–	**B2**	–	–
10:4	35-50	1	7	7	–	D	–	–	**D1**	–	–
10:5	35-50	1	5	5	–	O	P	R	**O1**	–	–
11:1	35-50	2	31	17	–	I	–	–	**B2**	–	–
11:2	35-50	2	8	12	–	I	–	–	**B2**	–	–
12:1	35-50	3	19	15	–	D	P	FH	**D2**	–	–
12:2	35-50	3	10	14	–	D	–	–	**D2**	–	–
13:1	35-50	4	20	11	–	D	D	R	**D2**	–	–
13:2	35-50	4	11	16	–	D	–	–	**D2**	–	–
13:3	35-50	4	15	13	–	I	–	–	**B2**	–	–

Cat. no.	Depth (cm)	Unit	T_1 (mm)	T_2 (mm)	Dia. (cm)	Rim dir.	Rim profile	Lip profile	Type	Carina-tion	Decora-tion
13:4	35-50	4	8	13	–	I	–	–	**B2**	–	–
13:5	35-50	4	8	13	–	I	–	–	**I3**	–	–
13:6	35-50	4	8	8	–	I	–	–	**I2**	–	–
13:7	35-50	4	12	13	–	D	–	–	**D2**	–	–
13:8	35-50	4	7	12	–	I	–	–	**I2**	–	–
13:9	35-50	4	7	8	–	I	–	–	**I2**	–	–
14:1	35-50	5	7	11	30	I	C	R	**I2**	–	–
14:2	35-50	5	7	9	–	I	–	–	**B2**	–	–
15:1	35-50	6	8	14	25	D	P	R	**D2**	–	–
15:2	35-50	6	12	7	17	I	D	R	**I1**	–	–
15:3	35-50	6	8	13	–	D	C	F	**D2**	–	–
15:4	35-50	6	8	15	35	D	C	R	**D2**	–	–
15:5	35-50	6	10	8	–	I	–	–	**I2**	–	–
16:1	35-50	7	8	11	35	D	D	R	**D1**	–	–
16:2	35-50	7	9	12	–	I	–	–	**I3**	–	–
16:3	35-50	7	–	–	–	–	–	–	–	–	PAD
17:1	35-50	8	19	21	35	I	P	R	**I3**	–	–
17:2	35-50	8	17	21	–	I	–	–	**I3**	–	–
17:3	35-50	8	15	16	–	I	–	–	**I3**	–	–
17:4	35-50	8	13	15	–	I	–	–	**I3**	–	–
17:5	35-50	8	18	27	–	I	–	–	**I3**	–	–
17:6	35-50	8	12	11	–	I	–	–	**I3**	–	–
17:7	35-50	8	5	12	–	D	–	–	**D2**	–	–
17:8	35-50	8	5	8	–	D	–	–	**D1**	–	–
17:9	35-50	8	2	6	–	O	C	P	**O3**	–	–
17:10	35-50	8	9	9	–	D	–	–	**D1**	–	–
17:11	35-50	8	6	9	–	D	–	–	**D1**	–	–
18:1	35-50	9	12	17	–	I	–	–	**B2**	–	–
18:2	35-50	9	13	10	35	I	D	FH	**I3**	–	–
18:3	35-50	9	11	11	35	I	P	F	**I2**	–	–
18:4	35-50	9	7	5	–	I	–	–	**B2**	–	–
18:5	35-50	9	7	7	–	I	–	–	**B2**	–	–
18:6	35-50	9	8	7	–	I	–	–	**I2**	–	–
20:1	50-65	2	6	4	–	O	–	–	**O1**	–	–
21:1	50-65	3	7	7	–	D	P	F	**D1**	–	–
21:2	50-65	3	10	9	–	I	–	–	**I2**	–	–
22:1	50-65	4	8	7	20	D	P	R	**D1**	–	–
22:2	50-65	4	9	14	40	D	C	FH	**D2**	–	–
24:1	50-65	6	18	14	–	I	–	–	**I3**	–	–
24:2	50-65	6	2	3	–	D	–	–	**D1**	–	–
24:3	50-65	6	–	–	–	–	–	–	–	–	PAD
25:1	50-65	7	6	7	–	I	–	–	**I2**	–	–
25:2	50-65	7	6	9	–	I	–	–	**I2**	–	–
26:1	50-65	8	10	8	30	I	D	–	**I2**	–	–
26:2	50-65	8	6	11	–	I	–	–	**I1**	–	–

Cat. no.	Depth (cm)	Unit	T_1 (mm)	T_2 (mm)	Dia. (cm)	Rim dir.	Rim profile	Lip profile	Type	Carina-tion	Decora-tion
27:1	50-65	9	19	8	–	I	–	–	**I3**	–	–
28:1	65-80	1	13	19	–	D	C	F	**D2**	–	–
28:2	65-80	1	8	7	–	D	P	F	**D1**	–	–
28:3	65-80	1	–	–	–	–	–	–	**–**	–	PAD
28:4	65-80	1	6	7	–	O	P	R	**O1**	–	–
29:1	65-80	2	9	8	–	–	–	–	**other**	–	–
29:2	65-80	2	5	9	–	I	–	–	**I1**	–	–
30:1	65-80	3	3	5	–	O	P	R	**O1**	–	–
30:2	65-80	3	3	4	–	I	–	–	**B1**	–	–
31:1	65-80	4	–	–	–	–	–	–	**–**	–	–
31:2	65-80	4	6	9	–	I	–	–	**B1**	–	–
33:1	65-80	6	10	10	21	D	P	R	**D1**	–	–
33:2	65-80	6	4	6	–	O	P	R	**O1**	–	–
37:1	80-90	1	4	5	–	I	P	FH	**I2**	–	–
37:2	80-90	1	5	6	–	I	–	–	**I2**	–	–
37:3	80-90	1	4	7	–	I	–	–	**I2**	–	–
38:1	80-90	2	11	12	27	D	P	FH	**D2**	–	–
38:2	80-90	2	11	12	30	D	P	F	**D2**	–	–
38:3	80-90	2	–	–	–	–	–	–	**–**	–	GR
39:1	80-90	3	9	14	40	D	C	FH	**D2**	–	–
39:2	80-90	3	8	12	–	D	–	–	**D2**	–	–
42:1	80-90	6	9	13	–	D	P	R	**D2**	–	–
42:2	80-90	–	–	–	–	–	–	–	–	–	–
43:1	80-90	7	9	10	30	D	P	R	**D1**	–	–
43:2	80-90	7	4	11	–	D	–	–	**D1**	–	–
44:1	80-90	8	14	14	–	D	P	R	**D2**	–	–
46:1	90-100	1	18	20	–	D	P	FH	**D2**	–	–
46:2	90-100	1	7	4	–	O	P	R	**O1**	–	–
47:1	90-100	2	10	13	–	I	P	R	**I3**	–	–
47:2	90-100	2	8	9	30	D	P	F	**D1**	–	–
47:3	90-100	2	5	8	–	D	–	–	**D1**	–	–
47:4	90-100	2	6	5	–	O	P	R	**O1**	–	–
47:5	90-100	2	6	10	–	O	C	R	**O2**	–	–
48:1	90-100	3	4	6	25	D	C	F	**D1**	–	–
48:2	90-100	3	9	10	–	D	–	–	**D1**	–	–
49:1	90-100	4	4	5	15	O	C	P	**O1**	–	–
49:2	90-100	4	13	15	–	D	P	R	**D2**	–	–
49:3	90-100	4	6	13	–	D	–	–	**D2**	–	–
49:4	90-100	4	9	15	–	I	–	–	**I3**	–	–
50:1	90-100	5	–	–	–	–	–	–	**–**	–	SH IMP
50:2	90-100	5	9	10	–	D	–	–	**D1**	–	–
50:3	90-100	5	14	14	–	D	–	–	**D2**	–	–
51:1	90-100	6	11	17	–	D	C	R	**D2**	–	–
51:2	90-100	6	8	11	–	D	C	FH	**D1**	–	–
51:3	90-100	6	8	12	–	D	C	FH	**D2**	–	–

Cat. no.	Depth (cm)	Unit	T_1 (mm)	T_2 (mm)	Dia. (cm)	Rim dir.	Rim profile	Lip profile	Type	Carina-tion	Decora-tion
51:4	90-100	6	6	11	–	D	–	–	**D1**	–	–
53:1	90-100	8	8	11	–	D	P	F	**D1**	–	–
55:1	100-110	1	10	9	–	D	D	FH	**D1**	–	–
55:2	100-110	1	3	5	–	O	P	R	**O1**	–	–
56:1	100-110	2	6	8	–	D	P	FH	**D1**	–	–
56:2	100-110	2	6	8	–	D	–	–	**D1**	–	–
56:3	100-110	2	9	17	–	I	–	–	**I3**	–	–
56:4	100-110	2	6	9	–	D	–	–	**D1**	–	–
57:1	100-110	3	7	6	25	D	D	R	**D1**	–	–
57:2	100-110	3	8	12	–	D	P	R	**D2**	–	–
57:3	100-110	3	6	15	–	D	C	FH	**D2**	–	–
57:4	100-110	3	8	10	–	D	P	F	**D1**	–	–
57:5	100-110	3	4	3	–	O	P	R	**O1**	–	–
57:6	100-110	3	5	9	–	D	–	–	**D1**	–	–
58:1	100-110	4	5	6	25	I	P	R	**B2**	–	–
58:2	100-110	4	4	5	–	O	P	R	**O1**	–	–
59:1	100-110	5	9	11	30	D	P	F	**D1**	–	–
59:2	100-110	5	9	11	35	D	P	F	**D1**	–	–
59:3	100-110	5	9	14	–	D	C	FH	**D2**	–	–
59:4	100-110	5	7	8	–	D	–	–	**D1**	–	–
59:5	100-110	5	3	3	–	O	P	R	**O1**	–	–
61:1	100-110	7	12	12	–	D	P	–	**D2**	–	–
61:2	100-110	7	4	8	–	D	–	–	**D1**	–	–
61:3	100-110	7	6	8	–	D	–	–	**D1**	–	–
61:4	100-110	7	7	7	–	D	–	–	**D1**	–	–
62:1	100-110	8	5	9	–	D	–	–	**D1**	–	–
63:1	110-120	9	5	8	30	D	C	R	**D1**	–	–
64:1	110-120	1	5	8	22	O	P	R	**O1**	–	–
64:2	110-120	1	3	6	25	D	C	P	**D1**	–	–
65:1	110-120	2	3	4	–	O	C	R	**O2**	–	–
65:2	110-120	2	3	8	–	D	–	–	**D1**	–	–
65:3	110-120	2	9	13	–	D	–	–	**D2**	–	–
67:1	110-120	4	9	12	35	D	C	F	**D2**	–	–
67:2	110-120	4	15	12	–	D	D	R	**D2**	–	–
67:3	110-120	4	–	14	–	–	–	–	**–**	–	–
67:4	110-120	4	12	14	–	D	–	–	**D2**	–	–
68:1	110-120	5	10	16	–	D	C	F	**D2**	–	–
68:2	110-120	5	14	18	–	D	P	R	**D2**	–	–
68:3	110-120	5	14	24	–	D	C	F	**D2**	–	–
68:4	110-120	5	11	10	–	O	P	R	**O1**	–	–
68:5	110-120	5	4	6	–	O	P	R	**O1**	–	–
68:6	110-120	5	–	–	–	–	–	–	**–**	×	–
68:7	110-120	5	7	11	–	D	–	–	**D1**	–	–
68:8-13	110-120	5	–	–	–	–	–	–	**–**	–	–
70:1	110-120	7	6	13	–	D	C	P	**D2**	–	–

Cat. no.	Depth (cm)	Unit	T_1 (mm)	T_2 (mm)	Dia. (cm)	Rim dir.	Rim profile	Lip profile	Type	Carina-tion	Decora-tion
70:2	110-120	7	5	12	–	D	C	F	**D2**	–	–
70:3	110-120	7	6	13	–	D	–	–	**D2**	–	–
70:4	110-120	7	6	9	–	D	–	–	**D1**	–	–
70:5	110-120	7	6	9	–	D	–	–	**D1**	–	–
70:6	110-120	7	6	9	–	D	–	–	**D1**	–	–
71:1	110-120	8	6	10	23	D	P	R	**D1**	–	–
71:2	110-120	8	5	7	–	I	–	–	**B2**	–	–
73:1	120-130	1	12	13	–	D	P	R	**D2**	–	–
73:2	120-130	1	12	11	–	D	P	F	**D1**	–	–
73:3	120-130	1	10	13	–	D	P	R	**D2**	–	–
73:4	120-130	1	5	8	–	O	P	R	**O1**	–	–
73:5	120-130	1	4	7	–	O	P	R	**O1**	–	–
74:1	120-130	2	13	14	–	D	P	R	**D2**	–	–
74:2	120-130	2	12	11	–	D	D	F	**D1**	–	–
74:3	120-130	2	6	9	–	I	C	R	**B2**	–	–
75:1	120-130	3	–	–	–	–	–	–	**–**	–	–
75:2	120-130	3	5	6	–	O	P	R	**O1**	–	–
75:3	120-130	3	6	10	–	O	P	R	**O1**	–	–
76:1	120-130	4	13	16	37	D	P	F	**D2**	–	–
76:2	120-130	4	12	13	–	D	–	–	**D2**	–	–
76:3	120-130	4	9	6	–	–	–	–	**–**	–	–
76:4	120-130	4	6	7	–	I	–	–	**I2**	–	–
76:5	120-130	4	–	–	–	D	P	F	**D2**	–	–
81:1	130-140	1	6	5	15	O	D	R	**O1**	–	–
81:2	130-140	1	5	4	20	O	C	P	**O3**	–	–
81:3	130-140	1	3	4	–	O	C	R	**O2**	–	–
81:4	130-140	1	4	5	–	O	P	R	**O1**	–	–
81:5	130-140	1	6	4	–	O	P	R	**O1**	–	–
81:6	130-140	1	3	7	–	O	C	R	**O2**	–	–
81:7	130-140	1	4	5	–	–	–	–	**–**	–	–
82:1	130-140	2	3	4	15	O	P	R	**O1**	–	–
82:2	130-140	2	4	5	20	O	P	R	**O1**	–	–
82:3	130-140	2	3	6	–	O	C	P	**O3**	–	–
82:4	130-140	2	6	8	–	O	P	R	**O1**	–	–
82:5	130-140	2	3	5	–	O	C	P	**O3**	–	–
83:1	130-140	3	4	6	25	O	C	P	**O3**	–	–
83:2	130-140	3	–	–	–	–	–	–	**–**	–	PUN LI
83:3	130-140	3	4	8	–	O	C	P	**O3**	–	–
83:4	130-140	3	5	7	–	O	P	R	**O1**	–	–
83:5	130-140	3	4	5	–	–	–	–	**–**	–	–
84:1	130-140	4	3	3	–	I	–	–	**I2**	–	–
84:2	130-140	4	4	4	–	O	P	R	**O1**	–	–
84:3	130-140	4	12	8	–	I	–	–	**I3**	–	–
84:4	130-140	4	6	5	–	O	P	R	**O1**	–	–
84:5	130-140	4	6	4	–	O	P	R	**O1**	–	–

Cat. no.	Depth (cm)	Unit	T_1 (mm)	T_2 (mm)	Dia. (cm)	Rim dir.	Rim profile	Lip profile	Type	Carina-tion	Decora-tion
84:6	130-140	4	3	3	–	O	P	R	**O1**	–	–
84:7	130-140	4	–	–	–	–	–	–	–	×	–
85:1	130-140	5	9	10	25	O	P	R	**O1**	–	–
85:2	130-140	5	4	5	–	O	P	R	**O1**	–	–
86:1	130-140	6	9	7	–	I	–	–	**I2**	–	–
86:2	130-140	6	5	3	–	O	P	R	**O1**	–	–
86:3	130-140	6	3	6	–	O	P	R	**O1**	–	–
86:4	130-140	6	–	–	–	–	–	–	–	×	–
86:5	130-140	6	–	–	–	–	–	–	–	×	–
87:1	130-140	7	15	18	35	I	P	R	**B2**	–	–
88:1	130-140	8	3	5	15	D	C	P	**D1**	–	–
88:2	130-140	8	5	6	20	O	P	R	**O1**	–	–
89:1	140-150	9	3	2	12	O	D	R	**O1**	–	–
89:2	140-150	9	4	5	17	O	C	R	**O2**	–	–
89:3	140-150	9	–	–	–	–	–	–	–	–	PUN
90:1	140-150	2	4	3	18	O	C	P	**O3**	–	–
90:2	140-150	2	5	6	–	O	P	R	**O1**	–	–
90:3	140-150	2	5	4	–	O	P	R	**O1**	–	–
90:4	140-150	2	4	2	–	O	P	R	**O1**	–	–
90:5	140-150	2	7	7	–	O	P	R	**O1**	–	–
90:6	140-150	2	5	3	–	–	–	–	–	–	–
91:1	140-150	3	3	2	–	–	–	–	–	–	–
91:2	140-150	3	–	–	–	O	P	R	**O1**	–	–
92:1	140-150	4	–	4	–	O	C	R	**O1**	–	–
92:2	140-150	4	6	5	–	O	D	R	**O1**	–	–
92:3	140-150	4	3	4	–	I	D	F	**I1**	–	–
92:4	140-150	4	–	–	–	–	–	–	–	–	DS
92:5	140-150	4	3	3	–	O	C	P	**O3**	–	–
92:6	140-150	4	–	–	–	–	–	–	–	–	–
92:7	140-150	4	9	9	9	D	P	R	**D1**	–	SH IMP
93:1	140-150	5	5	6	25	D	C	F	**D1**	–	–
93:2	140-150	5	3	7	25	D	C	F	**D1**	–	–
93:3	140-150	5	6	11	45	D	C	R	**D1**	–	–
93:4	140-150	5	3	4	–	O	P	R	**O1**	–	–
93:5	140-150	5	5	4	–	O	P	R	**O1**	–	–
94:1	140-150	6	3	3	15	O	P	R	**O1**	–	–
94:2	140-150	6	4	6	18	O	P	R	**O1**	–	–
94:3	140-150	6	4	5	–	O	P	R	**O1**	–	–
94:4	140-150	6	5	4	–	O	P	R	**O1**	–	–
94:5	140-150	6	4	4	–	–	–	–	–	–	–
94:6	140-150	6	4	5	–	O	C	P	**O3**	–	–
94:7	140-150	6	3	6	–	–	–	–	–	×	–
95:1	140-150	7	–	–	–	–	–	–	–	–	–
96:1	140-150	8	10	15	40	D	C	R	**D2**	–	–
96:2	140-150	8	11	12	–	D	–	R	**D2**	–	–

Cat. no.	Depth (cm)	Unit	T_1 (mm)	T_2 (mm)	Dia. (cm)	Rim dir.	Rim profile	Lip profile	Type	Carina-tion	Decora-tion
96:3	140-150	8	15	13	–	D	P	R	**D2**	–	–
96:4	140-150	8	14	15	–	D	C	R	**D2**	–	–
96:5	140-150	8	9	12	–	D	–	–	**D2**	–	–
97:1	150-160	1	3	4	15	O	P	R	**O1**	–	–
97:2	150-160	1	–	–	–	–	–	–	–	×	–
97:3	150-160	1	–	–	–	–	–	–	–	×	–
97:4	150-160	1	4	3	–	O	P	R	**O1**	–	–
100:1	150-160	4	4	5	17	O	P	R	**O1**	–	–
100:2	150-160	4	3	5	20	O	C	P	**O3**	–	–
100:3	150-160	4	3	5	25	O	C	P	**O3**	–	–
100:4	150-160	4	10	6	30	I	D	F	**I1**	–	–
100:5	150-160	4	3	5	34	O	C	P	**O3**	–	–
100:6	150-160	4	–	–	–	–	–	–	–	×	–
100:7	150-160	4	–	–	–	–	–	–	–	×	–
100:8	150-160	4	6	10	–	O	C	P	**O3**	–	–
100:9	150-160	4	7	8	–	O	P	R	**O1**	–	–
100:10	150-160	4	–	–	–	–	–	–	–	×	–
100:11	150-160	4	3	4	–	O	P	R	**O1**	–	–
100:12	150-160	4	–	–	–	O	–	–	–	–	–
101:1	150-160	5	6	4	15	O	D	FH	**O1**	–	–
101:2	150-160	5	6	5	–	I	–	–	**I2**	–	–
102:1	150-160	6	3	9	19	O	C	P	**O3**	–	–
102:2	150-160	6	2	4	20	O	P	R	**O1**	–	–
102:3	150-160	6	4	4	25	–	–	F	**other**	–	–
102:4	150-160	6	3	5	25	O	C	P	**O3**	–	–
102:5	150-160	6	–	–	–	–	–	–	–	×	–
102:6	150-160	6	–	–	–	O	P	R	**O1**	–	–
102:7	150-160	6	–	–	–	–	–	–	–	×	–
103:1	150-160	7	7	4	–	I	D	F	**B1**	–	–
103:2	150-160	7	–	–	–	–	–	–	–	–	IN LI
103:3	150-160	7	3	5	–	O	P	R	**O1**	–	–
103:4	150-160	7	2	5	–	O	P	R	**O1**	–	–
103:5	150-160	7	6	5	–	O	P	R	**O1**	–	–
103:6	150-160	7	–	–	–	–	–	–	–	–	–
104:1	150-160	8	11	13	–	D	P	F	**D2**	–	–
104:2	150-160	8	–	–	–	–	–	–	–	–	–
104:3	150-160	8	5	5	–	O	P	R	**O1**	–	–
104:4	150-160	8	2	4	–	O	C	P	**O3**	–	–
104:5	150-160	8	–	–	–	–	–	–	–	×	–
105:1	160-170	1	4	5	15	O	P	R	**O1**	–	–
105:2	160-170	1	3	5	18	O	P	R	**O1**	–	–
105:3	160-170	1	3	7	20	O	C	P	**O3**	–	–
105:4	160-170	1	3	8	22	O	C	P	**O3**	–	–
105:5	160-170	1	3	3	–	O	C	P	**O3**	–	–
105:6	160-170	1	–	–	–	–	–	–	–	–	–

Cat. no.	Depth (cm)	Unit	T_1 (mm)	T_2 (mm)	Dia. (cm)	Rim dir.	Rim profile	Lip profile	Type	Carina-tion	Decora-tion
105:7	160-170	1	–	–	–	–	–	–	–	–	–
107:1	160-170	3	3	4	17	O	C	P	**O3**	–	–
108:1	160-170	4	3	6	15	O	C	P	**O3**	–	–
108:2	160-170	4	5	6	20	O	C	R	**O1**	–	–
108:3	160-170	4	2	5	–	O	C	P	**O3**	–	–
108:4	160-170	4	–	–	–	–	–	–	–	–	–
109:1	160-170	5	9	9	30	D	P	F	**D1**	–	–
109:2	160-170	5	4	3	20	O	P	R	**O1**	–	–
109:3	160-170	5	6	4	–	O	P	R	**O1**	–	–
109:4	160-170	5	–	–	–	–	–	–	–	–	–
109:5	160-170	5	–	–	–	–	–	–	–	–	–
111:1	160-170	7	2	3	18	O	P	R	**O1**	–	–
111:2	160-170	7	5	11	22	I	C	F	**I1**	–	–
111:3	160-170	7	4	5	23	O	P	R	**O1**	–	–
111:4	160-170	7	3	4	–	O	P	R	**O1**	–	–
111:5	160-170	7	6	4	–	O	P	R	**O1**	–	–
111:6	160-170	7	6	4	–	O	P	R	**O1**	–	–
111:7	160-170	7	4	4	–	O	C	P	**O3**	–	–
112:1	160-170	8	2	3	20	O	C	P	**O3**	–	–
112:2	160-170	8	–	–	–	–	–	–	–	–	–
114:1	170-180	2	4	6	–	O	P	R	**O1**	–	–
114:2	170-180	2	4	4	–	O	P	R	**O1**	–	–
114:3	170-180	2	3	4	–	O	C	P	**O3**	–	–
115:1	170-180	3	3	5	20	O	P	R	**O1**	–	–
116:1	170-180	4	2	1	–	I	–	–	**B1**	–	–
116:2	170-180	4	6	5	–	O	P	R	**O1**	–	–
116:3	170-180	4	3	3	–	O	P	R	**O1**	–	–
116:4	170-180	4	4	5	–	O	P	R	**O1**	–	–
116:5	170-180	4	–	–	–	–	–	–	–	–	IN LI (SR)
117:1	170-180	5	5	5	17	O	P	R	**O1**	–	–
117:2	170-180	5	4	5	19	O	P	R	**O1**	–	–
117:3	170-180	5	–	–	–	–	–	–	–	–	–
118:1	170-180	6	–	–	–	–	–	–	–	–	STC
119:1	170-180	7	3	4	15	O	P	R	**O1**	–	–
119:2	170-180	7	–	–	–		P	R	**O1**	–	–
120:1	170-180	8	–	–	–	–	–	–	–	–	–
120:2	170-180	8	4	3	–	O	P	R	**O1**	–	–
120:3	170-180	8	4	6	–	O	C	R	**O2**	–	–
121:1	180-190	1	3	2	–	O	C	P	**O3**	–	–
121:2	180-190	1	5	6	–	O	C	P	**O3**	–	–
121:3	180-190	1	6	7	–	O	C	P	**O3**	–	–
122:1	180-190	2	5	3	–	O	P	R	**O1**	–	–
122:2	180-190	2	3	5	–	O	P	R	**O1**	–	–
122:3	180-190	2	5	6	–	O	P	R	**O1**	–	–

Cat. no.	Depth (cm)	Unit	T_1 (mm)	T_2 (mm)	Dia. (cm)	Rim dir.	Rim profile	Lip profile	Type	Carina-tion	Decora-tion
122:4	180-190	2	3	5	–	O	P	R	**O1**	–	–
124:1	180-190	4	–	–	–	–	–	–	–	×	–
124:2	180-190	4	–	–	–	–	–	–	–	×	–
124:3	180-190	4	–	–	–	–	–	–	–	×	–
124:4	180-190	4	7	5	–	O	P	R	**O1**	–	–
125:1	180-190	5	–	–	–	O	P	R	**O1**	–	–
125:2	180-190	5	6	8	–	O	P	R	**O1**	–	–
125:3	180-190	5	5	7	–	O	P	R	**O1**	–	–
125:4	180-190	5	–	–	–	–	–	–	–	–	–
126:1	180-190	6	6	6	–	O	P	R	**O1**	–	–
126:2	180-190	6	–	–	–	–	–	–	–	–	STC
127:1	180-190	7	–	–	–	–	–	–	–	–	–
127:2	180-190	7	3	6	–	O	C	R	**O2**	–	–
127:3	180-190	7	4	6	–	O	P	R	**O1**	–	–
127:4	180-190	7	3	5	–	O	P	R	**O1**	–	–
127:5	180-190	7	4	3	–	I	–	–	**I1**	–	–
127:6	180-190	7	4	5	–	O	P	R	**O1**	–	–
127:7	180-190	7	4	4	–	O	P	R	**O1**	–	–
128:1	180-190	8	–	–	–	–	–	–	–	×	–
128:2	180-190	8	2	4	–	O	C	P	**O3**	–	–
128:3	180-190	8	–	–	–	–	–	–	–	–	–
129:1	190-200	1	2	6	15	O	C	P	**O3**	–	–
129:2	190-200	1	3	5	25	O	C	P	**O3**	–	–
129:3	190-200	1	4	4	25	O	D	R	**O1**	–	–
129:4	190-200	1	3	5	–	O	P	R	**O1**	–	–
129:5	190-200	1	5	3	–	O	P	R	**O1**	–	–
129:6	190-200	1	3	4	–	O	P	R	**O1**	–	–
129:7	190-200	1	2	4	–	O	P	R	**O1**	–	–
129:8	190-200	1	2	4	–	O	C	P	**O3**	–	–
129:9	190-200	1	2	6	–	O	C	P	**O3**	–	–
130:1	190-200	2	4	3	17	O	P	R	**O1**	–	–
130:2	190-200	2	3	6	21	O	P	R	**O1**	–	–
130:3	190-200	2	3	7	–	O	C	P	**O3**	–	–
130:4	190-200	2	–	–	–	–	–	–	–	×	–
130:5	190-200	2	3	3	–	O	P	R	**O1**	–	–
130:6	190-200	2	3	5	–	O	P	R	**O1**	–	–
130:7	190-200	2	3	5	–	O	P	R	**O1**	–	–
130:8	190-200	2	3	5	–	O	P	R	**O1**	–	–
130:9	190-200	2	4	4	–	O	P	R	**O1**	–	–
130:10	190-200	2	3	6	–	O	C	P	**O3**	–	–
131:1	190-200	3	3	7	15	O	C	P	**O3**	–	–
131:2	190-200	3	3	3	20	O	P	R	**O1**	–	–
131:3	190-200	3	3	4	25	O	P	R	**O1**	–	–
131:4	190-200	3	–	–	–	–	–	–	–	×	–
131:5	190-200	3	4	6	–	O	P	R	**O1**	–	–

Cat. no.	Depth (cm)	Unit	T_1 (mm)	T_2 (mm)	Dia. (cm)	Rim dir.	Rim profile	Lip profile	Type	Carina-tion	Decora-tion
131:6	190-200	3	3	3	–	O	P	R	**O1**	–	–
131:7	190-200	3	4	7	–	O	P	R	**O1**	–	–
131:8	190-200	3	4	5	–	O	P	R	**O1**	–	–
131:9	190-200	3	–	–	–	–	–	–	–	×	–
131:10	190-200	3	–	–	–	–	–	–	–	–	IN LI (SR)
131:11	190-200	3	–	–	–	–	–	–	–	–	IN LI (SR)
132:1	190-200	4	5	8	14	O	D	R	**O1**	–	–
132:2	190-200	4	5	4	15	O	P	R	**O1**	–	–
132:3	190-200	4	3	6	–	O	P	R	**O1**	–	–
132:4	190-200	4	5	2	–	O	P	R	**O1**	–	–
132:5	190-200	4	4	4	–	O	P	R	**O1**	–	–
133:1	190-200	5	4	2	20	I	D	R	**B1**	–	–
133:2	190-200	5	3	2	–	O	P	R	**O1**	–	–
133:3	190-200	5	2	3	–	O	C	P	**O3**	–	–
133:4	190-200	5	3	6	–	O	P	R	**O1**	–	–
133:5	190-200	5	3	6	–	O	P	R	**O1**	–	–
133:6	190-200	5	5	4	–	O	P	R	**O1**	–	–
134:1	190-200	6	4	5	17	O	P	R	**O1**	–	–
134:2	190-200	6	2	5	19	O	C	P	**O3**	–	–
134:3	190-200	6	4	7	–	O	P	R	**O1**	–	–
134:4	190-200	6	4	6	–	O	P	R	**O1**	–	–
134:5	190-200	6	2	4	–	O	C	P	**O3**	–	–
134:6	190-200	6	–	–	25	–	–	–	–	×	–
136:1	190-200	7	3	5	–	O	C	P	**O3**	–	–
136:2	190-200	7	4	7	–	O	P	R	**O1**	–	–
136:3	190-200	7	3	6	–	O	C	P	**O3**	–	–
136:4	190-200	7	2	6	–	O	C	P	**O3**	–	–
136:6	190-200	7	3	4	–	O	P	R	**O1**	–	–
136:5	190-200	7	4	4	–	O	C	P	**O3**	–	–
136:7	190-200	7	3	4	–	O	P	R	**O1**	–	–
137:1	190-200	8	2	5	14	O	C	P	**O3**	–	–
137:2	190-200	8	4	6	21	O	P	R	**O1**	–	–
137:3	190-200	8	2	6	20	O	C	P	**O3**	–	–
137:4	190-200	8	4	7	–	O	C	P	**O3**	–	–
137:5	190-200	8	–	–	–	O	P	R	**O1**	–	–
138:1	200-210	1	4	5	25	O	P	R	**O1**	–	–
138:2	200-210	1	–	–	–	–	–	–	–	–	–
138:3	200-210	1	–	–	–	–	–	–	–	–	–
138:4	200-210	1	–	–	–	–	–	–	–	–	–
139:1	200-210	2	3	3	13	O	C	P	**O3**	–	–
139:2	200-210	2	3	4	20	O	C	P	**O3**	–	–
139:3	200-210	2	3	5	20	O	C	P	**O3**	–	–
139:4	200-210	2	3	5	–	O	C	P	**O3**	–	–

Cat. no.	Depth (cm)	Unit	T_1 (mm)	T_2 (mm)	Dia. (cm)	Rim dir.	Rim profile	Lip profile	Type	Carina-tion	Decora-tion
139:5	200-210	2	3	7	–	O	C	P	**O3**	–	–
139:6	200-210	2	4	6	–	O	P	R	**O1**	–	–
139:7	200-210	2	4	5	–	O	P	R	**O1**	–	–
139:8	200-210	2	4	6	–	O	P	R	**O1**	–	–
139:9	200-210	2	2	6	–	O	C	P	**O3**	–	–
139:10	200-210	2	–	–	–	–	–	–	**–**	×	–
139:11	200-210	2	5	3	–	O	P	R	**O1**	–	–
139:12	200-210	2	4	4	–	O	P	R	**O1**	–	–
140:1	200-210	3	3	5	–	O	P	R	**O1**	–	–
140:2	200-210	3	3	6	–	O	C	R	**O2**	–	–
140:3	200-210	3	4	5	–	O	P	R	**O1**	–	–
140:4	200-210	3	4	6	–	O	P	R	**O1**	–	–
140:5	200-210	3	4	5	–	O	P	R	**O1**	–	–
140:6	200-210	3	5	4	–	O	P	R	**O1**	–	–
140:7	200-210	3	3	4	–	O	P	R	**O1**	–	–
140:8	200-210	3	–	–	–	–	–	–	**–**	–	IN LI (SR)
140:9	200-210	3	–	–	–	–	–	–	**–**	–	IN LI (SR)
141:1	200-210	4	3	4	18	O	C	R	**O2**	–	–
141:2	200-210	4	4	2	15	O	C	P	**O3**	–	–
141:3	200-210	4	3	3	15	O	P	R	**O1**	–	–
141:4	200-210	4	3	3	20	O	P	R	**O1**	–	–
141:5	200-210	4	4	5	25	O	D	R	**O1**	–	–
141:6	200-210	4	4	5	30	O	P	R	**O1**	–	–
141:7	200-210	4	5	6	–	O	C	R	**O2**	–	–
141:8	200-210	4	3	6	–	O	C	P	**O3**	–	–
141:9	200-210	4	4	5	–	O	P	R	**O1**	–	–
141:10	200-210	4	4	2	–	D	–	–	**D1**	–	–
141:11	200-210	4	–	–	–	–	–	–	**–**	–	–
141:12	200-210	4	3	7	–	O	C	P	**O3**	–	–
141:13	200-210	4	2	4	–	O	C	P	**O3**	–	–
142:1	200-210	5	3	4	16	O	P	R	**O1**	–	–
142:2	200-210	5	5	6	–	O	P	R	**O1**	–	–
142:3	200-210	5	3	6	–	O	C	P	**O3**	–	–
142:4	200-210	5	6	8	–	D	–	–	**D1**	–	–
142:5	200-210	5	4	4	–	O	P	R	**O1**	–	–
142:6	200-210	5	–	–	–	–	–	–	**–**	–	–
142:7	200-210	5	1	5	–	O	C	P	**O3**	–	–
142:8	200-210	5	2	5	–	O	C	P	**O3**	–	–
142:9	200-210	5	–	–	–	–	–	–	**–**	–	IN LI (SR)
142:10	200-210	5	–	–	–	–	–	–	**–**	–	IN LI (SR)
143:1	200-210	6	3	1	18	O	P	R	**O1**	–	–
143:2	200-210	6	3	4	18	O	P	R	**O1**	–	–

Cat. no.	Depth (cm)	Unit	T_1 (mm)	T_2 (mm)	Dia. (cm)	Rim dir.	Rim profile	Lip profile	Type	Carina-tion	Decora-tion
143:3	200-210	6	3	5	–	O	C	R	**O2**	–	–
143:4	200-210	6	3	7	–	O	C	P	**O3**	–	–
143:5	200-210	6	5	3	–	O	P	R	**O1**	–	–
143:6	200-210	6	–	–	–	–	–	–	–	–	–
143:7	200-210	6	2	3	–	O	C	P	**O3**	–	–
144:1	200-210	7	4	4	20	O	P	R	**O1**	–	–
144:2	200-210	7	3	7	23	O	C	P	**O3**	–	–
144:3	200-210	7	3	5	–	O	C	R	**other**	–	–
145:1	200-210	8	3	4	20	I	–	R	**other**	–	–
145:2	200-210	8	3	2	20	I	D	R	**B1**	–	–
145:3	200-210	8	–	–	–	–	–	–	–	–	IN LI (SR)
145:4	200-210	8	–	–	–	–	–	–	–	–	IN LI (SR)
145:5	200-210	8	2	4	–	O	C	P	**O3**	–	–
146:1	210-220	1	3	5	15	O	C	P	**O3**	–	–
146:2	210-220	1	3	5	15	O	P	R	**O1**	–	STC
146:3	210-220	1	5	4	17	O	D	R	**O1**	–	–
146:4	210-220	1	3	4	20	O	P	R	**O1**	–	–
146:5	210-220	1	5	4	20	I	D	F	**B1**	–	–
146:6	210-220	1	5	4	25	O	D	R	**O1**	–	–
146:7	210-220	1	–	–	–	O	P	R	**O1**	–	–
146:8	210-220	1	4	5	–	O	P	R	**O1**	–	–
146:9	210-220	1	5	6	–	O	P	R	**O1**	–	–
146:10	210-220	1	4	6	–	O	P	R	**O1**	–	–
146:11	210-220	1	3	5	–	O	P	R	**O1**	–	–
146:12	210-220	1	3	4	–	O	P	R	**O1**	–	–
146:13	210-220	1	–	–	–	–	–	–	–	–	IN LI (SR)
146:14	210-220	1	–	–	–	–	–	–	–	–	IN/GR
147:1	210-220	2	4	3	15	O	D	R	**O1**	–	–
147:2	210-220	2	4	4	19	O	P	R	**O1**	–	–
147:3	210-220	2	3	5	22	O	P	–	**O1**	–	–
147:4	210-220	2	4	5	23	O	P	F	**O1**	–	–
147:5	210-220	2	4	5	–	O	C	P	**O3**	–	–
147:6	210-220	2	4	7	–	O	P	R	**O1**	–	–
147:7	210-220	2	3	6	–	O	C	P	**O3**	–	–
147:8	210-220	2	5	6	–	O	P	R	**O1**	–	–
148:1	210-220	3	5	4	17	O	P	R	**O1**	–	–
148:2	210-220	3	3	3	19	O	P	R	**O1**	–	–
148:3	210-220	3	3	6	20	O	P	R	**O1**	–	–
148:4	210-220	3	4	3	–	O	P	R	**O1**	–	–
148:5	210-220	3	6	8	–	O	P	R	**O1**	–	–
148:6	210-220	3	4	2	–	O	P	R	**O1**	–	–
148:7	210-220	3	2	7	–	O	C	P	**O3**	–	–

Cat. no.	Depth (cm)	Unit	T_1 (mm)	T_2 (mm)	Dia. (cm)	Rim dir.	Rim profile	Lip profile	Type	Carina-tion	Decora-tion
148:8	210-220	3	3	6	–	O	C	R	**O2**	–	–
149:1	210-220	4	3	6	29	O	C	P	**O3**	–	–
149:2	210-220	4	–	–	–	–	–	–	–	×	–
149:3	210-220	4	4	5	–	O	P	R	**O1**	–	–
149:4	210-220	4	4	4	–	O	P	R	**O1**	–	–
149:5	210-220	4	4	4	–	O	P	R	**O1**	–	–
149:6	210-220	4	5	7	–	O	C	P	**O3**	–	–
149:7	210-220	4	3	2	–	I	–	–	**B1**	–	–
149:8	210-220	4	3	5	–	O	P	R	**O1**	–	–
149:9	210-220	4	–	–	–	–	–	–	–	–	–
150:1	210-220	5	4	7	20	O	C	R	**O3**	–	–
150:2	210-220	5	4	6	–	O	C	P	**O3**	–	–
150:3	210-220	5	5	4	–	O	P	R	**O1**	–	–
150:4	210-220	5	4	5	–	O	P	R	**O1**	–	–
150:5	210-220	5	3	4	–	O	P	R	**O1**	–	–
150:6	210-220	5	–	–	–	–	–	–	–	×	–
151:1	210-220	6	2	5	11	O	C	P	**O3**	–	–
151:2	210-220	6	3	4	15	O	P	R	**O1**	–	–
151:3	210-220	6	4	4	22	O	P	R	**O1**	–	–
151:4	210-220	6	3	5	–	O	P	R	**O1**	–	–
151:5	210-220	6	3	7	–	O	C	P	**O3**	–	–
152:1	210-220	7	3	6	10	O	P	R	**O1**	–	–
152:2	210-220	7	2	6	15	–	–	–	**other**	–	–
152:3	210-220	7	4	6	20	O	P	R	**O1**	–	–
152:4	210-220	7	4	5	20	O	D	R	**O1**	–	–
152:5	210-220	7	3	4	25	O	C	R	**O1**	–	–
152:6	210-220	7	4	5	25	O	P	R	**O1**	–	–
152:7	210-220	7	2	4	–	O	C	P	**O3**	–	–
152:8	210-220	7	3	4	–	O	C	P	**O3**	–	–
152:9	210-220	7	–	–	–	–	–	–	–	–	IN
152:10	210-220	7	3	6	–	O	P	R	**O1**	–	–
152:11	210-220	7	4	5	–	O	P	R	**O1**	–	–
152:12	210-220	7	3	6	–	O	P	R	**O1**	–	–
152:13	210-220	7	3	6	–	O	P	R	**O1**	–	–
152:14	210-220	7	3	4	–	O	C	P	**O3**	–	–
152:15	210-220	7	2	4	–	O	C	P	**O3**	–	–
152:16	210-220	7	5	7	–	O	C	R	**O2**	–	–
152:17	210-220	7	–	–	–	–	–	–	–	–	–
152:18	210-220	7	3	5	–	O	C	P	**O3**	–	–
153:1	210-220	8	3	6	18	O	C	P	**O3**	–	–
153:2	210-220	8	2	5	18	O	C	P	**O3**	–	–
153:3	210-220	8	4	6	25	O	P	R	**O1**	–	–
153:4	210-220	8	2	4	–	O	P	R	**O1**	–	–
153:5	210-220	8	3	4	–	O	P	R	**O1**	–	–
153:6	210-220	8	2	4	–	O	P	R	**O1**	–	–

Cat. no.	Depth (cm)	Unit	T_1 (mm)	T_2 (mm)	Dia. (cm)	Rim dir.	Rim profile	Lip profile	Type	Carina-tion	Decora-tion
153:7	210-220	8	4	4	–	O	P	R	**O1**	–	–
153:8	210-220	8	3	5	–	O	C	P	**O3**	–	–
153:9	210-220	8	5	5	–	O	P	R	**O1**	–	–
153:10	210-220	8	7	4	–	O	P	R	**O1**	–	–
153:11	210-220	8	3	6	–	O	C	P	**O3**	–	–
153:12	210-220	8	–	–	–	–	–	–	–	–	IN LI (SR)
154:1	220-230	1	3	7	15	O	C	P	**O3**	–	–
154:2	220-230	1	4	6	15	O	–	–	**other**	–	–
154:3	220-230	1	5	6	20	O	P	R	**O1**	–	–
154:4	220-230	1	4	5	20	O	P	R	**O1**	–	–
154:5	220-230	1	7	6	23	O	D	R	**O1**	–	–
154:6	220-230	1	4	5	–	D	P	R	**other**	–	–
154:7	220-230	1	4	4	–	O	P	R	**O1**	–	–
154:8	220-230	1	4	4	–	O	P	R	**O1**	–	–
154:9	220-230	1	4	5	–	O	P	R	**O1**	–	–
154:10	220-230	1	5	4	–	O	P	R	**O1**	–	–
154:11	220-230	1	5	3	–	–	–	–	**other**	–	–
154:12	220-230	1	4	4	–	O	C	R	**O2**	–	–
154:13	220-230	1	4	6	–	O	P	R	**O1**	–	–
155:1	220-230	2	4	4	25	O	P	R	**O1**	–	–
155:2	220-230	2	3	5	–	O	P	R	**O1**	–	–
155:3	220-230	2	5	5	–	O	P	R	**O1**	–	–
155:4	220-230	2	3	6	–	O	C	P	**O3**	–	–
155:5	220-230	2	–	–	–	–	–	–	–	–	IN LI (SR)
156:1	230-240	1	4	6	14	O	P	R	**O1**	–	–
156:2	230-240	1	4	7	20	O	C	P	**O3**	–	–
156:3	230-240	1	5	6	20	O	P	R	**O1**	–	–
156:4	230-240	1	6	3	21	O	C	R	**O1**	–	–
157:1	220-230	1	5	3	20	I	D	FH	**B1**	–	–
157:2	220-230	1	5	4	25	O	P	R	**O1**	–	–
157:3	220-230	1	5	5	20	O	C	P	**O3**	–	–
157:4	220-230	1	4	4	16	O	P	R	**O1**	–	–
157:5	220-230	3	3	6	–	O	C	P	**O3**	–	–
157:6	220-230	3	7	5	–	O	P	R	**O1**	–	–
157:7	220-230	3	6	5	–	O	P	R	**O1**	–	–
157:8	220-230	3	3	4	–	O	C	P	**O3**	–	–
157:9	220-230	3	4	6	–	O	P	R	**O1**	–	–
157:10	220-230	3	–	–	–	–	–	–	**other**	–	–
158:1	220-230	4	5	6	18	O	P	R	**O1**	–	–
158:2	220-230	4	3	5	20	O	P	F	**O1**	–	–
158:3	220-230	4	4	6	20	O	P	R	**O1**	–	–
158:4	220-230	4	7	7	20	O	P	R	**O1**	–	–
158:5	220-230	4	5	6	25	O	P	R	**O1**	–	–

Cat. no.	Depth (cm)	Unit	T_1 (mm)	T_2 (mm)	Dia. (cm)	Rim dir.	Rim profile	Lip profile	Type	Carina-tion	Decora-tion
158:6	220-230	4	5	6	–	O	P	R	**O1**	–	–
158:7	220-230	4	–	–	–	–	–	–	–	×	–
158:8	220-230	4	–	–	–	–	–	–	–	–	–
158:9	220-230	4	4	8	–	O	P	R	**O1**	–	–
158:10	220-230	4	–	–	–	–	–	–	–	–	–
158:11	220-230	4	5	3	–	O	P	R	**O1**	–	–
158:12	220-230	4	6	7	–	O	P	R	**O1**	–	–
158:13	220-230	4	5	3	–	O	P	R	**O1**	–	–
158:14	220-230	4	4	6	–	O	C	R	**O2**	–	–
158:15	220-230	4	4	6	–	O	C	P	**O3**	–	–
159:1	220-230	5	4	7	17	O	P	R	**O1**	–	–
159:2	220-230	5	5	8	18	O	C	P	**O3**	–	–
159:3	220-230	5	4	5	19	O	D	R	**O1**	–	–
159:4	220-230	5	4	3	20	O	P	R	**O1**	–	–
159:5	220-230	5	4	3	23	O	P	R	**O1**	–	–
159:6	220-230	5	5	6	23	O	C	R	**O1**	–	–
159:7	220-230	5	4	6	28	O	P	R	**O1**	–	–
159:8	220-230	5	7	11	35	O	C	P	**O3**	–	–
159:9	220-230	5	4	4	–	O	P	R	**O1**	–	–
159:10	220-230	5	4	6	–	O	P	R	**O1**	–	–
159:11	220-230	5	4	3	–	O	P	R	**O1**	–	–
159:12	220-230	5	6	6	–	D	–	–	**D1**	–	–
159:13	220-230	5	4	9	–	O	P	R	**O1**	–	–
159:14	220-230	5	4	5	–	O	P	R	**O1**	–	–
159:15	220-230	5	–	–	–	–	–	–	–	×	–
159:16	220-230	5	–	–	–	–	–	–	–	×	–
159:17	220-230	5	2	4	–	O	C	P	**O3**	–	–
159:18	220-230	5	–	–	–	–	–	–	–	–	IN LI (SR)
160:1	220-230	6	3	5	18	O	P	R	**O1**	–	–
160:2	220-230	6	3	6	22	O	D	R	**O1**	–	–
160:3	220-230	6	4	6	23	O	D	R	**O1**	–	–
160:4	220-230	6	2	6	23	O	C	P	**O3**	–	–
160:5	220-230	6	4	5	25	O	P	R	**O1**	–	–
160:6	220-230	6	3	7	–	O	C	P	**O3**	–	–
160:7	220-230	6	3	6	–	O	C	R	**O2**	–	–
160:8	220-230	6	3	5	–	O	C	P	**O3**	–	–
160:9	220-230	6	4	5	–	O	C	P	**O3**	–	–
160:10	220-230	6	4	6	–	O	C	P	**O3**	–	–
160:11	220-230	6	3	5	–	O	P	R	**O1**	–	–
160:12	220-230	6	3	5	–	O	P	R	**O1**	–	–
161:1	230-240	1	–	–	–	–	–	–	–	–	IN LI (SR)
162:1	230-240	1	6	6	10	O	P	R	**O1**	–	–
162:2	230-240	2	4	5	–	O	P	R	**O1**	–	–

Cat. no.	Depth (cm)	Unit	T_1 (mm)	T_2 (mm)	Dia. (cm)	Rim dir.	Rim profile	Lip profile	Type	Carina-tion	Decora-tion
162:3	230-240	2	5	6	–	O	P	R	**O1**	–	–
162:4	230-240	2	6	6	–	O	P	R	**O1**	–	–
162:5	230-240	2	3	–	–	–	–	–	–	–	–
163:1	230-240	3	5	3	15	O	D	F	**O1**	–	–
163:2	230-240	3	6	8	15	O	C	R	**O2**	–	–
163:3	230-240	3	4	5	15	O	C	P	**O3**	–	–
163:4	230-240	3	2	6	20	O	C	P	**O3**	–	–
163:5	230-240	3	7	9	25	O	P	R	**O1**	–	–
163:6	230-240	3	4	6	–	O	C	P	**O3**	–	–
163:7	230-240	3	4	6	–	O	C	P	**O3**	–	–
163:8	230-240	3	2	6	–	O	C	P	**O3**	–	–
163:9	230-240	3	4	7	–	O	C	P	**O3**	–	–
163:10	230-240	3	5	6	–	O	C	P	**O3**	–	–
163:11	230-240	3	5	5	–	O	P	R	**O1**	–	–
163:12	230-240	3	6	7	–	O	P	R	**O1**	–	–
163:13	230-240	3	3	4	–	O	P	R	**O1**	–	–
163:14	230-240	3	7	6	–	O	P	R	**O1**	–	–
163:15	230-240	3	–	–	–	–	–	–	–	–	–
163:16	230-240	3	–	–	–	–	–	–	–	–	–
163:17	230-240	3	–	–	–	–	–	–	–	–	–
163:18	230-240	3	8	7	–	O	C	P	**O3**	–	–
163:19	230-240	3	5	6	–	O	C	R	**O2**	–	–
163:20	230-240	3	5	6	–	O	P	R	**O1**	–	–
163:21	230-240	3	5	7	–	O	P	R	**O1**	–	–
163:22	230-240	3	4	6	–	O	C	P	**O3**	–	–
163:23	230-240	3	5	6	–	O	P	R	**O1**	–	–
163:24	230-240	3	4	3	–	O	C	P	**O3**	–	–
163:25	230-240	3	–	–	–	–	–	–	–	×	–
163:26	230-240	3	–	–	–	–	–	–	–	×	–
163:27	230-240	3	–	–	–	–	–	–	–	×	–
163:28	230-240	3	–	–	–	–	–	–	–	×	–
164:1	240-250	1	–	–	–	–	–	–	–	–	IN LI (SR)
164:2	240-250	1	5	7	–	O	P	R	**O1**	–	–
164:3	240-250	1	4	2	–	O	P	R	**O1**	–	–
164:4	240-250	1	4	6	–	–	–	–	–	–	–
164:5	240-250	1	4	4	–	O	P	R	**O1**	–	–
165:1	240-250	1	5	6	18	O	P	R	**O1**	–	–
165:2	240-250	2	5	6	20	O	P	R	**O1**	–	–
165:3	240-250	2	4	3	14	O	D	FH	**O1**	–	–
165:4	240-250	2	3	2	17	O	D	R	**O1**	–	–
165:5	240-250	2	5	5	–	O	P	R	**O1**	–	–
165:6	240-250	2	5	6	–	O	P	R	**O1**	–	–
165:7	240-250	2	4	4	–	O	P	R	**O1**	–	–
165:8	240-250	2	–	–	–	–	–	–	–	–	–

Cat. no.	Depth (cm)	Unit	T_1 (mm)	T_2 (mm)	Dia. (cm)	Rim dir.	Rim profile	Lip profile	Type	Carina-tion	Decora-tion
165:9	240-250	2	–	–	–	–	–	–	–	–	–
167:1	250-260	2	–	–	–	–	–	–	–	–	DS (ACH)
168:1	250-260	3	4	6	–	O	C	P	**O3**	–	–
168:2	250-260	4	5	8	–	O	P	R	**O1**	–	–
168:3	250-260	4	–	–	–	–	–	–	–	–	–
169:1	240-250	4	3	6	17	O	C	P	**O3**	–	–
169:2	240-250	4	3	4	20	O	D	P	**O3**	–	–
169:3	240-250	4	4	5	21	O	P	R	**O1**	–	–
169:4	240-250	4	3	6	25	O	C	P	**O3**	–	–
169:5	240-250	4	5	4	–	O	P	R	**O1**	–	–
169:6	240-250	4	3	4	–	O	P	R	**O1**	–	–
169:7	240-250	4	3	5	–	O	C	R	**O2**	–	–
169:8	240-250	4	7	5	–	I	–	–	**I2**	–	–
169:9	240-250	4	3	6	–	O	C	P	**O3**	–	–
169:10	240-250	4	3	5	–	O	C	R	**O2**	–	–
169:11	240-250	4	3	4	–	O	P	R	**O1**	–	–
169:12	240-250	4	2	5	–	O	P	R	**O1**	–	–
169:13	240-250	4	3	5	–	O	C	P	**O3**	–	–
169:14	240-250	4	3	4	–	O	P	R	**O1**	–	–
169:15	240-250	4	4	4	–	–	–	–	–	–	–
169:16	240-250	4	–	–	–	–	–	–	–	–	–
169:17	240-250	4	–	–	–	–	–	–	–	–	–
169:18	240-250	4	–	–	–	–	–	–	–	–	–
170:1	230-240	5	3	4	17	O	P	R	**O1**	–	–
170:2	230-240	5	4	3	19	O	C	P	**O3**	–	–
170:3	230-240	5	5	4	20	O	P	R	**O1**	–	–
170:4	230-240	5	2	4	20	O	C	P	**O3**	–	–
170:5	230-240	5	4	3	20	O	D	R	**O1**	–	–
170:6	230-240	5	4	2	18	O	D	R	**O1**	–	–
170:7	230-240	5	3	4	25	O	P	R	**O1**	–	–
170:8	230-240	5	4	6	–	O	D	R	**O1**	–	–
170:9	230-240	5	–	–	–	–	–	–	–	×	–
170:10	230-240	5	–	–	–	–	–	–	–	×	–
170:11	230-240	5	–	–	–	–	–	–	–	–	–
170:12	230-240	5	–	–	–	–	–	–	–	–	IN LI (SR)
170:13	230-240	5	–	–	–	–	–	–	–	–	IN LI (SR)
170:14	230-240	5	–	–	–	–	–	–	–	–	IN LI (SR)
172:1	240-250	5	5	3	14	O	D	R	**O1**	–	–
172:2	240-250	5	4	3	15	O	D	R	**O1**	–	–
172:3	240-250	5	4	4	15	O	P	R	**O1**	–	–
172:4	240-250	5	4	4	–	O	P	R	**O1**	–	–
172:5	240-250	5	3	7	–	O	C	P	**O3**	–	–

Cat. no.	Depth (cm)	Unit	T_1 (mm)	T_2 (mm)	Dia. (cm)	Rim dir.	Rim profile	Lip profile	Type	Carina-tion	Decora-tion
172:6	240-250	5	3	5	–	O	C	P	**O3**	–	–
172:7	240-250	5	–	–	–	–	–	–	–	–	–
172:8	240-250	5	6	8	–	O	P	R	**O1**	–	–
172:9	240-250	5	4	3	–	O	P	R	**O1**	–	–
172:10	240-250	5	–	–	–	–	–	–	–	–	–
172:11	240-250	5	3	5	–	O	P	R	**O1**	–	–
172:12	240-250	5	4	5	–	O	P	R	**O1**	–	–
172:13	240-250	5	3	4	–	O	C	P	**O3**	–	–
172:14	240-250	5	3	6	–	O	C	P	**O3**	–	–
172:15	240-250	5	–	–	–	–	–	–	–	–	–
172:16	240-250	5	–	–	–	–	–	–	–	–	–
172:17	240-250	5	4	4	–	–	–	–	–	–	–
172:18	240-250	5	3	5	–	O	P	R	**O1**	–	–
172:19	240-250	5	4	4	–	O	P	R	**O1**	–	–
172:20	240-250	5	–	–	–	–	–	–	–	–	PUN
172:21	240-250	5	–	–	–	O	C	P	**O3**	–	
173:1	240-250	6	4	5	17	D	D	R	**other**	–	–
173:2	240-250	6	3	5	20	O	D	P	**O1**	–	–
173:3	240-250	6	6	4	20	O	D	R	**O1**	–	–
173:4	240-250	6	7	8	23	O	P	R	**O1**	–	–
173:5	240-250	6	6	5	–	O	D	P	**other**	–	–
173:6	240-250	6	4	5	–	O	C	P	**O3**	–	–
173:7	240-250	6	4	5	–	D	–	–	**D1**	–	–
173:8	240-250	6	4	7	–	O	C	P	**O3**	–	–
173:9	240-250	6	4	5	–	O	C	P	**O3**	–	–
173:10	240-250	6	–	–	–	O	C	P	**O3**	–	–
173:11	240-250	6	–	–	–	O	C	P	**O3**	–	–
173:12	240-250	6	–	–	–	–	–	–	–	–	–
173:13	240-250	6	3	2	–	O	D	R	**other**	–	–
173:14	240-250	6	–	–	–	–	–	–	–	–	–
173:15	240-250	6	4	4	–	O	P	R	**O1**	–	–
174:1	250-260	4	5	5	25	O	C	P	**O3**	–	–
174:2	250-260	4	–	–	–	–	–	–	–	×	–
174:3	250-260	4	–	–	–	–	–	–	–	×	–
174:4	250-260	4	4	5	–	O	P	R	**O1**	–	–
174:5	250-260	4	6	4	–	O	P	R	**O1**	–	–
174:6	250-260	4	6	5	–	O	P	R	**O1**	–	–
174:7	250-260	4	4	5	–	O	P	R	**O1**	–	–
174:8	250-260	4	4	8	–	O	C	P	**O3**	–	–
174:9	250-260	4	5	5	–	O	P	R	**O1**	–	–
174:10	250-260	4	–	–	–	–	–	–	–	×	–
174:11	250-260	4	–	–	–	–	–	–	–	×	–
174:12	250-260	4	–	–	–	–	–	–	–	–	–
174:13	250-260	4	–	–	–	–	–	–	–	–	–
174:14	250-260	4	4	3	–	O	C	R	**O2**	–	–
175:1	250-260	5	4	4	13	O	P	R	**O1**	–	–

Cat. no.	Depth (cm)	Unit	T_1 (mm)	T_2 (mm)	Dia. (cm)	Rim dir.	Rim profile	Lip profile	Type	Carina-tion	Decora-tion
175:2	250-260	5	4	6	15	O	P	R	**O1**	–	–
175:3	250-260	5	5	4	20	O	P	R	**O1**	–	–
175:4	250-260	5	5	3	20	O	D	R	**O1**	–	–
175:5	250-260	5	5	6	20	O	P	R	**O1**	–	–
175:6	250-260	5	4	5	–	O	P	R	**O1**	–	–
175:7	250-260	5	5	6	–	O	P	R	**O1**	–	–
175:8	250-260	5	5	6	–	O	P	R	**O1**	–	–
175:9	250-260	5	–	–	–	–	–	–	**–**	–	–
176:1	250-260	6	4	3	11	O	D	R	**O1**	–	–
176:2	250-260	6	3	3	15	O	D	R	**O1**	–	–
176:3	250-260	6	3	6	10	O	P	R	**O1**	–	–
176:4	250-260	6	5	4	30	O	D	R	**O1**	–	–
176:5	250-260	6	4	8	30	O	C	R	**O2**	–	–
176:6	250-260	6	2	3	–	O	C	P	**O3**	–	–
176:7	250-260	6	3	4	–	O	C	P	**O3**	–	–
176:8	250-260	6			–	O	D	R	**O1**	–	–
Feature K:1	245-275	–	3	6	–	O	C	P	**O3**	–	–
Feature K:2	245-275	–	6	3	–	O	P	R	**O1**	–	–
Feature K:3	245-275	–	3	3	–	O	C	P	**O3**	–	–
Feature K:4	245-275	–	3	6	–	O	C	P	**O3**	–	–
Feature K:5	245-275	–	2	3	–	O	C	P	**O3**	–	–
Feature K:6	245-275	–	6	5	–	O	P	R	**O1**	–	–
Feature K:7	245-275	–	4	5	–	O	P	R	**O1**	–	–
Feature K:8	245-275	–	2	4	–	O	C	P	**O3**	–	–
Feature K:9	245-275	–	4	4	–	O	P	R	**O1**	–	–
Feature K:10	245-275	–	–	–	–	–	–	–	**–**	–	STC

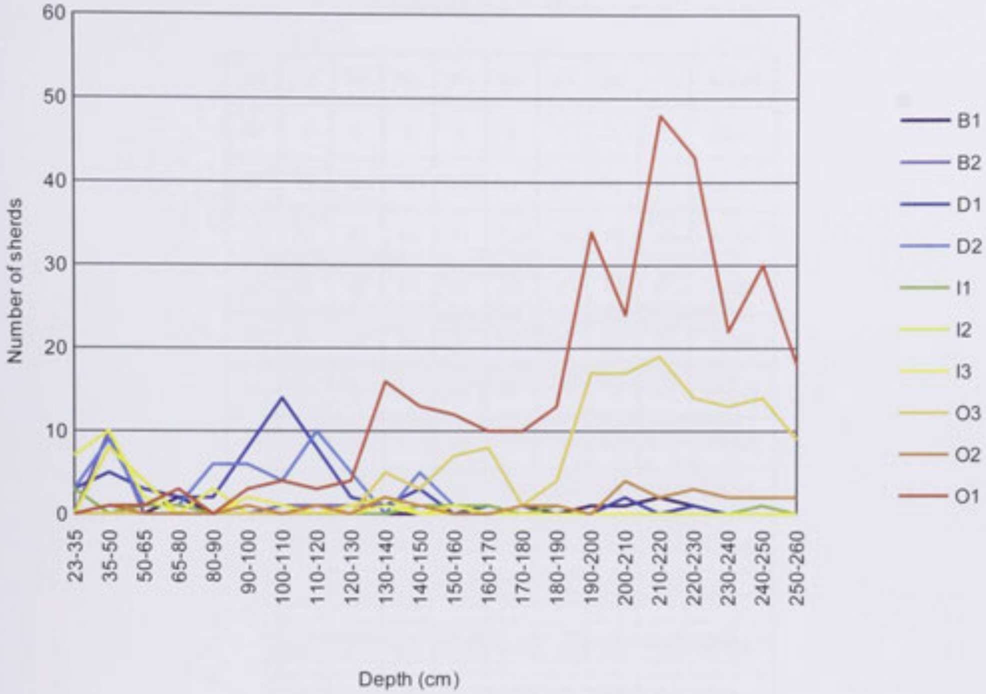


Fig 1-5. Distribution of types.

Fig 1-6. Catalog number reference matrix.

Depth	U1	U2	U3	U4	U5	U6	U7	U8	U9
23-35	1	2	3	4	5	6	7	8	9
35-50	10	11	12	13	14	15	16	17	18
50-65	19	20	21	22	23	24	25	26	27
65-80	28	29	30	31	32	33	34	35	36
80-90	37	38	39	40	41	42	43	44	45
90-100	46	47	48	49	50	51	52	53	54
100-110	55	56	57	58	59	60	61	62	63
110-120	64	65	66	67	68	69	70	71	72
120-130	73	74	75	76	77	78	79	80	BURI-AL
130-140	81	82	83	84	85	86	87	88	
140-150	89	90	91	92	93	94	95	96	
150-160	97	98	99	100	101	102	103	104	
160-170	105	106	107	108	109	110	111	112	
170-180	113	114	115	116	117	118	119	120	
180-190	121	122	123	124	125	126	127	128	
190-200	129	130	131	132	133	134	136	137	
200-210	138	139	140	141	142	143	144	145	
210-220	146	147	148	149	150	151	152	153	
220-230	154	155	157	158	159	160			
230-240	156	161	162	163	170	171			
240-250	164	165	166	169	172	173			
250-260		167	168	174	175	176			

Table 1-2. List of analysed material.

Lab. no.	Cat. no	Petrographic thin section	Pore line analysis
BAT 1	176:8	x	x
BAT 3	172:21	x	x
BAT 4	170:1	x	x
BAT 6	170:2	x	x
BAT 10	160:3	x	x
BAT 11	159:3	x	x
BAT 14	159:1	x	x
BAT 16	145:2	x	x
BAT 17	143:1	x	x
BAT 20	129:2	x	x
BAT 22	125:4	x	x
BAT 25	100:8	x	–
BAT 27	153:3	–	x
BAT 28	137:5	–	x
BAT 29	119:2	–	x
BAT 30	117:3	–	x
BAT 31	100:12	–	x
BAT 32	91:2	–	x
BAT 33	76:5	–	x
BAT 34	62:1	–	x
BAT 35	42:2	–	x
BAT 36	3:1	–	x

The following sherds were prepared but not analysed: 139:2; 143:2; 143:2; 147:3; 150:3; 152:7; 152:8; 156:4; 159:5; 169:1; 169:3; 170:6; 176:5:

BAT 1 (Cat. no. 176:8)

Data sheet

Fig 1-7.

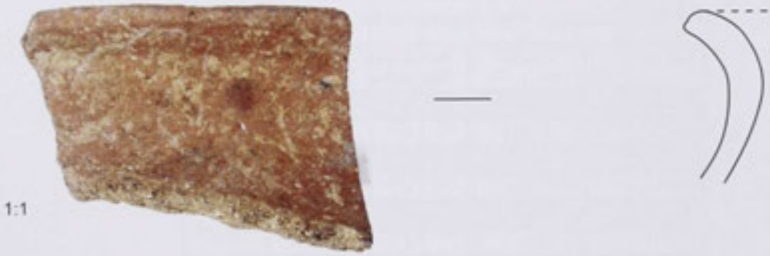


Fig 1-8.

Fig 1-9.

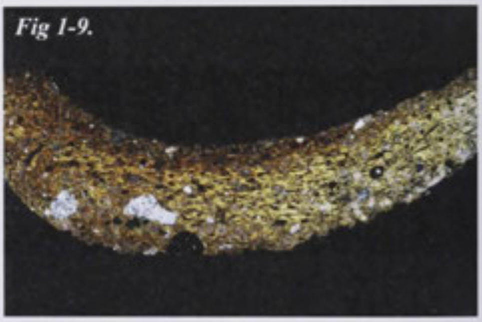


Table 1-3. Temper data.

Class	% Cumulative
0.02-0.03	0
0.03-0.04	0.3
0.04-0.05	1.49
0.05-0.06	3.58
0.06-0.07	7.31
0.07-0.08	10.15
0.08-0.09	14.33
0.09-0.10	16.27
0.10-0.11	17.91
0.11-0.12	19.4
0.12-0.13	21.64
0.13-0.14	22.84
0.14-0.15	25.22
0.15-0.16	28.51
0.16-0.17	30.9
0.17-0.18	33.43
0.18-0.19	35.52
0.19-0.20	38.06
0.20-0.21	40.75
0.21-0.22	42.84
0.22-0.23	45.37
0.23-0.24	48.21
0.24-0.25	50.9
0.25-0.26	54.78
0.26-0.27	58.06
0.27-0.28	60.9
0.28-0.29	63.13
0.29-0.30	65.22
0.30-0.31	68.36
0.31-0.32	70.3
0.32-0.33	72.24
0.33-0.34	74.63
0.34-0.35	76.42
0.35-0.36	77.46
0.36-0.37	79.55
0.37-0.38	81.64
0.38-0.39	82.39
0.39-0.40	83.58
0.40-0.41	84.93
0.41-0.42	85.52
0.42-0.43	86.42
0.43-0.44	87.31
0.44-0.45	88.06
0.45-0.46	88.81
0.46-0.47	89.55
0.47-0.48	91.04
0.48-0.49	91.94
0.49-0.50	92.69
0.50-0.51	93.73
0.51-0.52	99.47
0.52-0.53	99.47
0.53-0.54	99.47
0.54-0.55	99.47
0.55-0.56	99.56
0.56-0.57	99.74
0.57-0.58	99.82
0.58-0.59	99.82
0.59-0.60	99.82
0.60-0.61	99.82
0.61-0.62	99.82
0.62-0.63	99.82
0.63-0.64	99.82
0.64-0.65	99.82
0.65-0.66	99.91
0.66-0.67	99.91
0.67-0.68	99.91
0.68-0.69	99.91
0.69-0.7	99.91
0.7-0.71	100

BAT 3 (Cat. no.172:21)

Data sheet

Fig 1-10.

1:1

Fig 1-11.

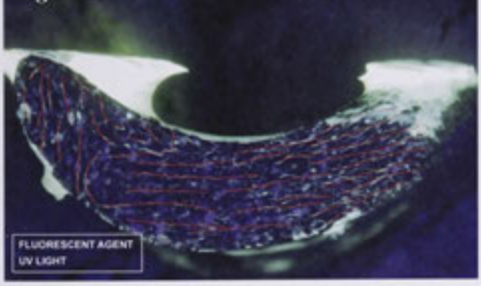


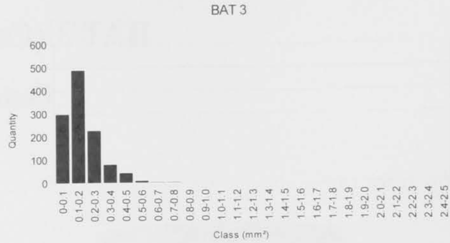
Fig 1-12.

Table 1-4. Temper data.

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
1136			

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.02-0.03	3	0.26	3	0.26
0.03-0.04	22	1.94	25	2.2
0.04-0.05	41	3.61	66	5.81
0.05-0.06	52	4.58	118	10.39
0.06-0.07	37	3.26	155	13.64
0.07-0.08	50	4.4	205	18.05
0.08-0.09	47	4.14	252	22.18
0.09-0.1	44	3.87	296	26.06
0.1-0.11	68	5.99	364	32.04
0.11-0.12	51	4.49	415	36.53
0.12-0.13	62	5.46	477	41.99
0.13-0.14	52	4.58	529	46.57
0.14-0.15	48	4.23	577	50.79
0.15-0.16	54	4.75	631	55.55
0.16-0.17	48	4.23	679	59.77
0.17-0.18	28	2.46	707	62.24
0.18-0.19	46	4.05	753	66.29
0.19-0.2	30	2.64	783	68.93
0.2-0.21	40	3.52	823	72.45
0.21-0.22	30	2.64	853	75.09
0.22-0.23	30	2.64	883	77.73
0.23-0.24	25	2.2	908	79.93
0.24-0.25	21	1.85	929	81.78
0.25-0.26	27	2.38	956	84.15
0.26-0.27	21	1.85	977	86
0.27-0.28	14	1.23	991	87.24
0.28-0.29	7	0.62	998	87.85
0.29-0.3	10	0.88	1008	88.73

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.3-0.31	13	1.14	1021	89.88
0.31-0.32	9	0.79	1030	90.67
0.32-0.33	11	0.97	1041	91.64
0.33-0.34	7	0.62	1048	92.25
0.34-0.35	11	0.97	1059	93.22
0.35-0.36	7	0.62	1066	93.84
0.36-0.37	8	0.7	1074	94.54
0.37-0.38	3	0.26	1077	94.81
0.38-0.39	8	0.7	1085	95.51
0.39-0.4	1	0.09	1086	95.6
0.4-0.41	5	0.44	1091	96.04
0.41-0.42	3	0.26	1094	96.3
0.42-0.43	8	0.7	1102	97.01
0.43-0.44	6	0.53	1108	97.54
0.44-0.45	7	0.62	1115	98.15
0.45-0.46	5	0.44	1120	98.59
0.46-0.47	3	0.26	1123	98.86
0.47-0.48	1	0.09	1124	98.94
0.48-0.49	2	0.18	1126	99.12
0.49-0.5	1	0.09	1127	99.21
0.5-0.51	1	0.09	1128	99.3
0.51-0.52	2	0.18	1130	99.47
0.52-0.53	0	0	1130	99.47
0.53-0.54	0	0	1130	99.47
0.54-0.55	0	0	1130	99.47
0.55-0.56	1	0.09	1131	99.56
0.56-0.57	2	0.18	1133	99.74
0.57-0.58	1	0.09	1134	99.82
0.58-0.59	0	0	1134	99.82
0.59-0.6	0	0	1134	99.82
0.6-0.61	0	0	1134	99.82
0.61-0.62	0	0	1134	99.82
0.62-0.63	0	0	1134	99.82
0.63-0.64	0	0	1134	99.82
0.64-0.65	0	0	1134	99.82
0.65-0.66	1	0.09	1135	99.91
0.66-0.67	0	0	1135	99.91
0.67-0.68	0	0	1135	99.91
0.68-0.69	0	0	1135	99.91
0.69-0.7	0	0	1135	99.91
0.7-0.71	1	0.09	1136	100



BAT 4 (Cat. no. 170:1)

Data sheet

Fig 1-13.

1:1

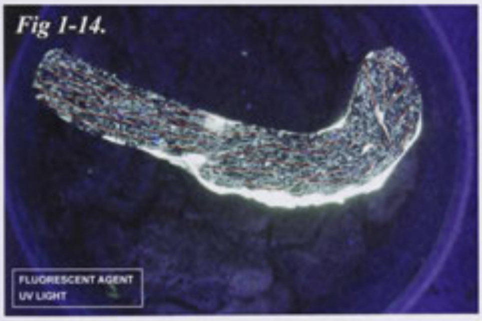


Fig 1-14.

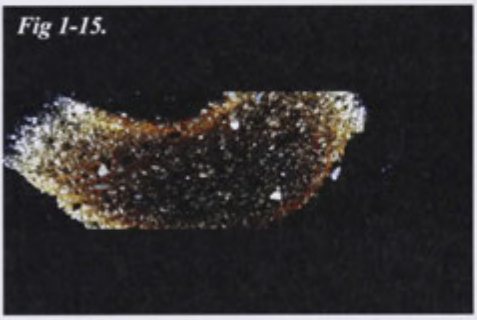


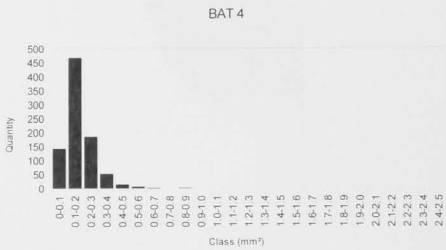
Fig 1-15.

Table 1-5. Temper data.

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
870			

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.02-0.03	1	0.11	1	0.11
0.03-0.04	4	0.46	5	0.57
0.04-0.05	21	2.41	26	2.99
0.05-0.06	14	1.61	40	4.6
0.06-0.07	13	1.49	53	6.09
0.07-0.08	23	2.64	76	8.74
0.08-0.09	29	3.33	105	12.07
0.09-0.1	37	4.25	142	16.32
0.1-0.11	45	5.17	187	21.49
0.11-0.12	51	5.86	238	27.36
0.12-0.13	52	5.98	290	33.33
0.13-0.14	51	5.86	341	39.2
0.14-0.15	39	4.48	380	43.68
0.15-0.16	46	5.29	426	48.97
0.16-0.17	55	6.32	481	55.29
0.17-0.18	38	4.37	519	59.66
0.18-0.19	45	5.17	564	64.83
0.19-0.2	45	5.17	609	70
0.2-0.21	38	4.37	647	74.37
0.21-0.22	30	3.45	677	77.82
0.22-0.23	17	1.95	694	79.77
0.23-0.24	22	2.53	716	82.3
0.24-0.25	16	1.84	732	84.14
0.25-0.26	15	1.72	747	85.86
0.26-0.27	16	1.84	763	87.7
0.27-0.28	15	1.72	778	89.43
0.28-0.29	11	1.26	789	90.69
0.29-0.3	5	0.57	794	91.26
0.3-0.31	6	0.69	800	91.95
0.31-0.32	10	1.15	810	93.1
0.32-0.33	7	0.8	817	93.91

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.33-0.34	7	0.8	824	94.71
0.34-0.35	8	0.92	832	95.63
0.35-0.36	6	0.69	838	96.32
0.36-0.37	1	0.11	839	96.44
0.37-0.38	1	0.11	840	96.55
0.38-0.39	4	0.46	844	97.01
0.39-0.4	2	0.23	846	97.24
0.4-0.41	3	0.34	849	97.59
0.41-0.42	1	0.11	850	97.7
0.42-0.43	1	0.11	851	97.82
0.43-0.44	2	0.23	853	98.05
0.44-0.45	0	0	853	98.05
0.45-0.46	2	0.23	855	98.28
0.46-0.47	2	0.23	857	98.51
0.47-0.48	2	0.23	859	98.74
0.48-0.49	1	0.11	860	98.85
0.49-0.5	0	0	860	98.85
0.5-0.51	1	0.11	861	98.97
0.51-0.52	1	0.11	862	99.08
0.52-0.53	0	0	862	99.08
0.53-0.54	1	0.11	863	99.2
0.54-0.55	1	0.11	864	99.31
0.55-0.56	0	0	864	99.31
0.56-0.57	0	0	864	99.31
0.57-0.58	1	0.11	865	99.43
0.58-0.59	1	0.11	866	99.54
0.59-0.6	0	0	866	99.54
0.6-0.61	2	0.23	868	99.77
0.61-0.62	0	0	868	99.77
0.62-0.63	0	0	868	99.77
0.63-0.64	0	0	868	99.77
0.64-0.65	0	0	868	99.77
0.65-0.66	0	0	868	99.77
0.66-0.67	0	0	868	99.77
0.67-0.68	0	0	868	99.77
0.68-0.69	0	0	868	99.77
0.69-0.7	0	0	868	99.77
0.7-0.71	0	0	868	99.77
0.71-0.72	0	0	868	99.77
0.72-0.73	0	0	868	99.77
0.73-0.74	0	0	868	99.77
0.74-0.75	0	0	868	99.77
0.75-0.76	0	0	868	99.77
0.76-0.77	0	0	868	99.77
0.77-0.78	0	0	868	99.77
0.78-0.79	0	0	868	99.77
0.79-0.8	0	0	868	99.77
0.8-0.81	0	0	868	99.77
0.81-0.82	0	0	868	99.77
0.82-0.83	0	0	868	99.77
0.83-0.84	1	0.11	869	99.89
0.84-0.85	0	0	869	99.89
0.85-0.86	0	0	869	99.89
0.86-0.87	1	0.11	870	100



BAT 6 (Cat. no. 170:2)

Data sheet

Fig 1-16.

Fig 1-17.

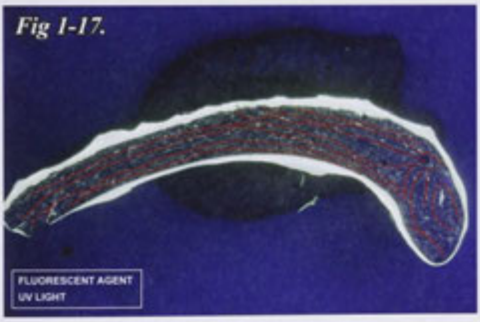


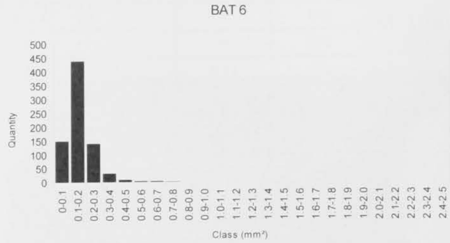
Fig 1-18.

Table 1-6. Temper data.

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
772			

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.02-0.03	2	0.26	2	0.26
0.03-0.04	8	1.03	10	1.29
0.04-0.05	22	2.85	32	4.14
0.05-0.06	22	2.85	54	6.99
0.06-0.07	15	1.94	69	8.93
0.07-0.08	23	2.98	92	11.9
0.08-0.09	34	4.4	126	16.3
0.09-0.1	23	2.98	149	19.28
0.1-0.11	39	5.05	188	24.32
0.11-0.12	39	5.05	227	29.37
0.12-0.13	44	5.69	271	35.06
0.13-0.14	62	8.02	333	43.08
0.14-0.15	57	7.37	390	50.45
0.15-0.16	55	7.12	445	57.57
0.16-0.17	56	7.24	501	64.81
0.17-0.18	30	3.88	531	68.69
0.18-0.19	32	4.14	563	72.83
0.19-0.2	24	3.1	587	75.94
0.2-0.21	32	4.14	619	80.08
0.21-0.22	23	2.98	642	83.05
0.22-0.23	16	2.07	658	85.12

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.23-0.24	12	1.55	670	86.68
0.24-0.25	8	1.03	678	87.71
0.25-0.26	13	1.68	691	89.39
0.26-0.27	7	0.91	698	90.3
0.27-0.28	9	1.16	707	91.46
0.28-0.29	8	1.03	715	92.5
0.29-0.3	12	1.55	727	94.05
0.3-0.31	5	0.65	732	94.7
0.31-0.32	3	0.39	735	95.08
0.32-0.33	0	0	735	95.08
0.33-0.34	5	0.65	740	95.73
0.34-0.35	5	0.65	745	96.38
0.35-0.36	4	0.52	749	96.9
0.36-0.37	4	0.52	753	97.41
0.37-0.38	4	0.52	757	97.93
0.38-0.39	1	0.13	758	98.06
0.39-0.4	0	0	758	98.06
0.4-0.41	2	0.26	760	98.32
0.41-0.42	0	0	760	98.32
0.42-0.43	1	0.13	761	98.45
0.43-0.44	2	0.26	763	98.71
0.44-0.45	0	0	763	98.71
0.45-0.46	1	0.13	764	98.84
0.46-0.47	0	0	764	98.84
0.47-0.48	1	0.13	765	98.97
0.48-0.49	1	0.13	766	99.09
0.49-0.5	0	0	766	99.09
0.5-0.51	1	0.13	767	99.22
0.51-0.52	0	0	767	99.22
0.52-0.53	0	0	767	99.22
0.53-0.54	0	0	767	99.22
0.54-0.55	0	0	767	99.22
0.55-0.56	1	0.13	768	99.35
0.56-0.57	0	0	768	99.35
0.57-0.58	0	0	768	99.35
0.58-0.59	1	0.13	769	99.48
0.59-0.6	0	0	769	99.48
0.6-0.61	0	0	769	99.48
0.61-0.62	1	0.13	770	99.61
0.62-0.63	0	0	770	99.61
0.63-0.64	0	0	770	99.61
0.64-0.65	1	0.13	771	99.74
0.65-0.66	0	0	771	99.74
0.66-0.67	1	0.13	772	99.87
0.67-0.68	0	0	772	99.87
0.68-0.69	0	0	772	99.87
0.69-0.7	0	0	772	99.87
0.7-0.71	0	0	772	99.87
0.71-0.72	0	0	772	99.87
0.72-0.73	1	0.13	773	100



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Data sheet

Fig 1-19.

Fig 1-20.

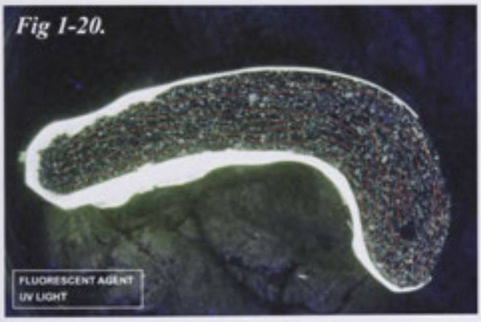

Fig 1-21.

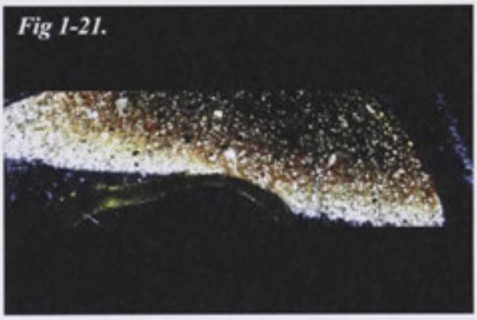

Table 1-7. Temper data.

Class	% Cumulative
0.02-0.03	0.22
0.03-0.04	2.22
0.04-0.05	7.63
0.05-0.06	12.93
0.06-0.07	17.85
0.07-0.08	23.04
0.08-0.09	27.69
0.09-0.10	31.37
0.10-0.11	35.64
0.11-0.12	40.29
0.12-0.13	45.75
0.13-0.14	51.22
0.14-0.15	56.46
0.15-0.16	61.22
0.16-0.17	65.87
0.17-0.18	70.52
0.18-0.19	74.26
0.19-0.20	78.58
0.20-0.21	82.1
0.21-0.22	85.45
0.22-0.23	87.4
0.23-0.24	89.18
0.24-0.25	90.64
0.25-0.26	92.21
0.26-0.27	93.13
0.27-0.28	93.89
0.28-0.29	94.75
0.29-0.30	95.51
0.30-0.31	95.84
0.31-0.32	96.16
0.32-0.33	96.7
0.33-0.34	97.13
0.34-0.35	97.35
0.35-0.36	97.73
0.36-0.37	97.84
0.37-0.38	97.94
0.38-0.39	98.16
0.39-0.40	98.43
0.40-0.41	98.43
0.41-0.42	98.59
0.42-0.43	98.65
0.43-0.44	98.86
0.44-0.45	98.97
0.45-0.46	99.13
0.46-0.47	99.13
0.47-0.48	99.19
0.48-0.49	99.24
0.49-0.50	99.35
0.50-0.51	99.35
0.51-0.52	99.09
0.52-0.53	99.22
0.53-0.54	99.35
0.54-0.55	99.35
0.55-0.56	99.35
0.56-0.57	99.42
0.57-0.58	99.55
0.58-0.59	99.61
0.59-0.60	99.68
0.60-0.61	99.68
0.61-0.62	99.74
0.62-0.63	99.74
0.63-0.64	99.87
0.64-0.65	99.87
0.65-0.66	99.87
0.66-0.67	99.87
0.67-0.68	99.94
1.55-1.56	100

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Data sheet

Fig 1-22.

1:1

Fig 1-23.

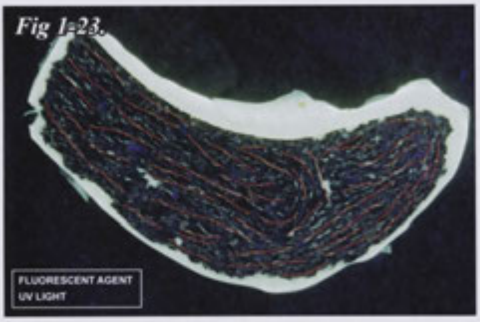

Fig 1-24.

Table 1-8. Temper data.

Class	% Cumulative
0.02-0.03	0.13
0.03-0.04	0.71
0.04-0.05	2.33
0.05-0.06	4.34
0.06-0.07	6.93
0.07-0.08	9.32
0.08-0.09	12.04
0.09-0.10	14.76
0.10-0.11	17.02
0.11-0.12	19.55
0.12-0.13	22.78
0.13-0.14	25.31
0.14-0.15	27.25
0.15-0.16	30.29
0.16-0.17	33.85
0.17-0.18	37.86
0.18-0.19	41.62
0.19-0.20	45.76
0.20-0.21	50.29
0.21-0.22	55.02
0.22-0.23	59.29
0.23-0.24	62.78
0.24-0.25	66.93
0.25-0.26	70.23
0.26-0.27	73.72
0.27-0.28	76.89
0.28-0.29	79.48
0.29-0.30	82.33
0.30-0.31	84.34
0.31-0.32	86.28
0.32-0.33	87.38
0.33-0.34	88.67
0.34-0.35	89.97
0.35-0.36	90.94
0.36-0.37	91.84
0.37-0.38	92.82
0.38-0.39	93.85
0.39-0.40	94.76
0.40-0.41	95.53
0.41-0.42	95.99
0.42-0.43	96.44
0.43-0.44	96.89
0.44-0.45	97.28
0.45-0.46	97.67
0.46-0.47	98.06
0.47-0.48	98.45
0.48-0.49	98.71
0.49-0.50	98.83
0.50-0.51	99.03
0.51-0.52	95.65
0.52-0.53	96.17
0.53-0.54	96.7
0.54-0.55	96.97
0.55-0.56	97.23
0.56-0.57	97.76
0.57-0.58	97.89
0.58-0.59	98.15
0.59-0.60	98.15
0.60-0.61	98.42
0.61-0.62	98.68
0.62-0.63	99.08
0.63-0.64	99.08
0.64-0.65	99.21
0.65-0.66	99.21
0.66-0.67	99.21
0.67-0.68	99.21
0.68-0.69	99.6
0.69-0.7	99.74
0.7-0.71	99.74
0.71-0.72	99.74
0.72-0.73	99.74
0.73-0.74	99.74
0.74-0.75	100

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Data sheet

Fig 1-25.

Fig 1-26.

Fig 1-27.

Table 1-9. Temper data.

Class	% Cumulative
0.02-0.03	0.26
0.03-0.04	1.06
0.04-0.05	1.98
0.05-0.06	5.94
0.06-0.07	10.55
0.07-0.08	14.64
0.08-0.09	19.26
0.09-0.10	24.01
0.10-0.11	27.31
0.11-0.12	29.29
0.12-0.13	31.93
0.13-0.14	34.17
0.14-0.15	38.13
0.15-0.16	40.24
0.16-0.17	42.74
0.17-0.18	44.99
0.18-0.19	47.1
0.19-0.20	49.34
0.20-0.21	52.9
0.21-0.22	55.67
0.22-0.23	57.78
0.23-0.24	60.42
0.24-0.25	62.66
0.25-0.26	65.17
0.26-0.27	67.28
0.27-0.28	68.34
0.28-0.29	69.66
0.29-0.30	71.37
0.30-0.31	74.01
0.31-0.32	75.46
0.32-0.33	77.57
0.33-0.34	78.89
0.34-0.35	81.27
0.35-0.36	83.25
0.36-0.37	84.43
0.37-0.38	85.36
0.38-0.39	86.15
0.39-0.40	88.26
0.40-0.41	89.18
0.41-0.42	90.24
0.42-0.43	91.56
0.43-0.44	92.48
0.44-0.45	93.27
0.45-0.46	93.93
0.46-0.47	94.46
0.47-0.48	94.59
0.48-0.49	94.72
0.49-0.50	95.12
0.50-0.51	95.51
0.51-0.52	99.47
0.52-0.53	99.56
0.53-0.54	99.56
0.54-0.55	99.56
0.55-0.56	99.56
0.56-0.57	99.74
0.57-0.58	99.74
0.58-0.59	99.74
0.59-0.60	99.74
0.60-0.61	99.74
0.61-0.62	99.74
0.62-0.63	99.74
0.63-0.64	99.82
...	
0.72-0.73	99.91
...	
0.87-0.88	100

BAT 16 (Cat. no. 145:2)

Data sheet

Fig 1-28.

1:1

Fig 1-29.

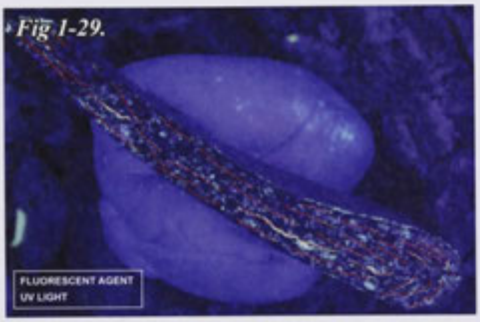


Fig 1-30.

Table 1-10. Temper data.

Class	% Cumulative
0.02-0.03	0.11
0.03-0.04	0.45
0.04-0.05	2.9
0.05-0.06	6.58
0.06-0.07	10.26
0.07-0.08	14.27
0.08-0.09	17.06
0.09-0.10	20.07
0.10-0.11	22.85
0.11-0.12	26.31
0.12-0.13	30.21
0.13-0.14	33.78
0.14-0.15	36.45
0.15-0.16	40.13
0.16-0.17	44.04
0.17-0.18	48.16
0.18-0.19	52.06

Class	% Cumulative
0.19-0.20	57.19
0.20-0.21	60.31
0.21-0.22	63.77
0.22-0.23	66.56
0.23-0.24	70.01
0.24-0.25	73.02
0.25-0.26	75.47
0.26-0.27	78.71
0.27-0.28	81.27
0.28-0.29	83.17
0.29-0.30	85.4
0.30-0.31	86.29
0.31-0.32	87.4
0.32-0.33	88.96
0.33-0.34	90.75
0.34-0.35	91.3
0.35-0.36	92.42
0.36-0.37	93.2
0.37-0.38	94.09
0.38-0.39	94.76

Class	% Cumulative
0.39-0.40	95.54
0.40-0.41	95.99
0.41-0.42	96.54
0.42-0.43	96.88
0.43-0.44	97.21
0.44-0.45	97.55
0.45-0.46	97.88
0.46-0.47	97.99
0.47-0.48	98.1
0.48-0.49	98.1
0.49-0.50	98.33
0.50-0.51	98.44
0.51-0.52	98.55
0.52-0.53	98.66
0.53-0.54	98.66
0.54-0.55	98.66
0.55-0.56	98.77
0.56-0.57	99
0.57-0.58	99.11
0.58-0.59	99.11

Class	% Cumulative
0.59-0.60	99.11
0.60-0.61	99.22
0.61-0.62	99.22
0.62-0.63	99.22
0.63-0.64	99.22
0.64-0.65	99.22
0.65-0.66	99.33
…	
0.7-0.71	99.44
…	
0.79-0.8	99.55
0.8-0.81	99.67
0.81-0.82	99.67
0.82-0.83	99.67
0.83-0.84	99.89
…	
0.87-0.88	100

BAT 17 (Cat. no. 143:1)

Data sheet

Fig 1-31.

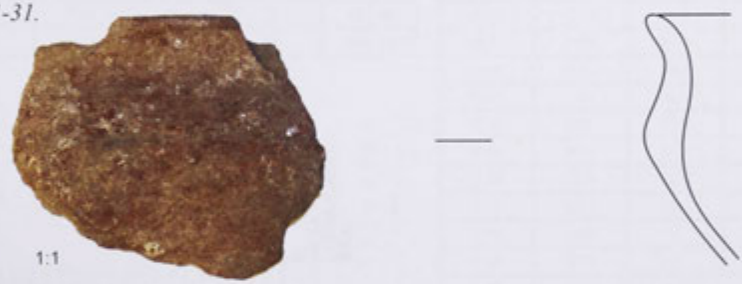


Fig 1-32.

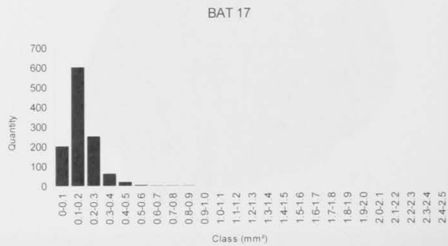
Fig 1-33.

Table 1-11. Temper data.

Number of Objects	Area Fraction	Area (mm²)	Measured Area (mm²)
1142			

Class	Number	% Number	Cumulative	% Cumulative
0.02-0.03	2	0.18	2	0.18
0.03-0.04	4	0.35	6	0.53
0.04-0.05	20	1.75	26	2.28
0.05-0.06	26	2.28	52	4.55
0.06-0.07	36	3.15	88	7.71
0.07-0.08	28	2.45	116	10.16
0.08-0.09	47	4.12	163	14.27
0.09-0.1	38	3.33	201	17.6
0.1-0.11	46	4.03	247	21.63
0.11-0.12	61	5.34	308	26.97
0.12-0.13	71	6.22	379	33.19
0.13-0.14	79	6.92	458	40.11
0.14-0.15	52	4.55	510	44.66
0.15-0.16	62	5.43	572	50.09
0.16-0.17	55	4.82	627	54.9
0.17-0.18	63	5.52	690	60.42
0.18-0.19	60	5.25	750	65.67
0.19-0.2	52	4.55	802	70.23
0.2-0.21	36	3.15	838	73.38
0.21-0.22	42	3.68	880	77.06
0.22-0.23	33	2.89	913	79.95
0.23-0.24	31	2.71	944	82.66
0.24-0.25	22	1.93	966	84.59
0.25-0.26	30	2.63	996	87.22
0.26-0.27	21	1.84	1017	89.05
0.27-0.28	9	0.79	1026	89.84
0.28-0.29	15	1.31	1041	91.16
0.29-0.3	12	1.05	1053	92.21
0.3-0.31	10	0.88	1063	93.08
0.31-0.32	9	0.79	1072	93.87
0.32-0.33	9	0.79	1081	94.66

Class	Number	% Number	Cumulative	% Cumulative
0.33-0.34	7	0.61	1088	95.27
0.34-0.35	7	0.61	1095	95.88
0.35-0.36	8	0.7	1103	96.58
0.36-0.37	2	0.18	1105	96.76
0.37-0.38	2	0.18	1107	96.94
0.38-0.39	6	0.53	1113	97.46
0.39-0.4	2	0.18	1115	97.64
0.4-0.41	5	0.44	1120	98.07
0.41-0.42	3	0.26	1123	98.34
0.42-0.43	5	0.44	1128	98.77
0.43-0.44	2	0.18	1130	98.95
0.44-0.45	2	0.18	1132	99.12
0.45-0.46	2	0.18	1134	99.3
0.46-0.47	0	0	1134	99.3
0.47-0.48	0	0	1134	99.3
0.48-0.49	0	0	1134	99.3
0.49-0.5	1	0.09	1135	99.39
0.5-0.51	0	0	1135	99.39
0.51-0.52	1	0.09	1136	99.47
0.52-0.53	1	0.09	1137	99.56
0.53-0.54	0	0	1137	99.56
0.54-0.55	0	0	1137	99.56
0.55-0.56	0	0	1137	99.56
0.56-0.57	2	0.18	1139	99.74
0.57-0.58	0	0	1139	99.74
0.58-0.59	0	0	1139	99.74
0.59-0.6	0	0	1139	99.74
0.6-0.61	0	0	1139	99.74
0.61-0.62	0	0	1139	99.74
0.62-0.63	0	0	1139	99.74
0.63-0.64	1	0.09	1140	99.82
0.64-0.65	0	0	1140	99.82
0.65-0.66	0	0	1140	99.82
0.66-0.67	0	0	1140	99.82
0.67-0.68	0	0	1140	99.82
0.68-0.69	0	0	1140	99.82
0.69-0.7	0	0	1140	99.82
0.7-0.71	0	0	1140	99.82
0.71-0.72	0	0	1140	99.82
0.72-0.73	1	0.09	1141	99.91
0.73-0.74	0	0	1141	99.91
0.74-0.75	0	0	1141	99.91
0.75-0.76	0	0	1141	99.91
0.76-0.77	0	0	1141	99.91
0.77-0.78	0	0	1141	99.91
0.78-0.79	0	0	1141	99.91
0.79-0.8	0	0	1141	99.91
0.8-0.81	0	0	1141	99.91
0.81-0.82	0	0	1141	99.91
0.82-0.83	0	0	1141	99.91
0.83-0.84	0	0	1141	99.91
0.84-0.85	0	0	1141	99.91
0.85-0.86	0	0	1141	99.91
0.86-0.87	0	0	1141	99.91
0.87-0.88	1	0.09	1142	100



BAT 20 (Cat. no. 129:2)

Data sheet

Fig 1-34.

Fig 1-35.

Fig 1-36.

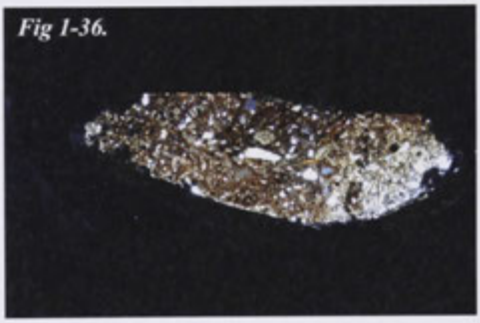
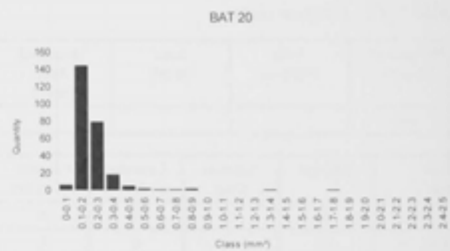


Table 1-12. Temper data.

Number of Objects	Area Fraction	Area (mm²)	Measured Area (mm²)
260			

Class (mm²)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.02-0.03	0	0	0	0
0.03-0.04	0	0	0	0
0.04-0.05	0	0	0	0
0.05-0.06	0	0	0	0
0.06-0.07	1	0.38	1	0.38
0.07-0.08	0	0	1	0.38
0.08-0.09	4	1.54	5	1.92
0.09-0.1	1	0.38	6	2.31
0.1-0.11	4	1.54	10	3.85
0.11-0.12	9	3.46	19	7.31
0.12-0.13	6	2.31	25	9.62
0.13-0.14	19	7.31	44	16.92
0.14-0.15	21	8.08	65	25
0.15-0.16	17	6.54	82	31.54
0.16-0.17	25	9.62	107	41.15
0.17-0.18	14	5.38	121	46.54
0.18-0.19	21	8.08	142	54.62
0.19-0.2	8	3.08	150	57.69
0.2-0.21	16	6.15	166	63.85
0.21-0.22	7	2.69	173	66.54
0.22-0.23	10	3.85	183	70.38
0.23-0.24	6	2.31	189	72.69
0.24-0.25	8	3.08	197	75.77
0.25-0.26	8	3.08	205	78.85
0.26-0.27	7	2.69	212	81.54
0.27-0.28	9	3.46	221	85
0.28-0.29	3	1.15	224	86.15
0.29-0.3	5	1.92	229	88.08
0.3-0.31	3	1.15	232	89.23

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.31-0.32	2	0.77	234	90
0.32-0.33	1	0.38	235	90.38
0.33-0.34	1	0.38	236	90.77
0.34-0.35	4	1.54	240	92.31
0.35-0.36	1	0.38	241	92.69
0.36-0.37	2	0.77	243	93.46
0.37-0.38	2	0.77	245	94.23
0.38-0.39	1	0.38	246	94.62
0.39-0.4	1	0.38	247	95
0.4-0.41	0	0	247	95
0.41-0.42	1	0.38	248	95.38
0.42-0.43	0	0	248	95.38
0.43-0.44	2	0.77	250	96.15
0.44-0.45	1	0.38	251	96.54
0.45-0.46	0	0	251	96.54
0.46-0.47	0	0	251	96.54
0.47-0.48	0	0	251	96.54
0.48-0.49	1	0.38	252	96.92
0.49-0.5	0	0	252	96.92
0.5-0.51	0	0	252	96.92
0.51-0.52	1	0.38	253	97.31
0.52-0.53	0	0	253	97.31
0.53-0.54	0	0	253	97.31
0.54-0.55	1	0.38	254	97.69
0.55-0.56	0	0	254	97.69
0.56-0.57	0	0	254	97.69
0.57-0.58	0	0	254	97.69
0.58-0.59	0	0	254	97.69
0.59-0.6	0	0	254	97.69
0.6-0.61	0	0	254	97.69
0.61-0.62	0	0	254	97.69
0.62-0.63	0	0	254	97.69
0.63-0.64	0	0	254	97.69
0.64-0.65	0	0	254	97.69
0.65-0.66	1	0.38	255	98.08
0.66-0.67	0	0	255	98.08
0.67-0.68	0	0	255	98.08
0.68-0.69	0	0	255	98.08
0.69-0.7	0	0	255	98.08
0.7-0.71	0	0	255	98.08
0.71-0.72	0	0	255	98.08
0.72-0.73	0	0	255	98.08
0.73-0.74	1	0.38	256	98.46
0.74-0.75	0	0	256	98.46
0.75-0.76	0	0	256	98.46
0.76-0.77	0	0	256	98.46
0.77-0.78	0	0	256	98.46
0.78-0.79	0	0	256	98.46
0.79-0.8	0	0	256	98.46
0.8-0.81	0	0	256	98.46
0.81-0.82	1	0.38	257	98.85
0.82-0.83	1	0.38	258	99.23
0.83-0.84	0	0	258	99.23
0.84-0.85	0	0	258	99.23
0.85-0.86	0	0	258	99.23
0.86-0.87	0	0	258	99.23
0.87-0.88	0	0	258	99.23
0.88-0.89	0	0	258	99.23
0.89-0.9	0	0	258	99.23
0.9-0.91	0	0	258	99.23
0.91-0.92	0	0	258	99.23
0.92-0.93	0	0	258	99.23
0.93-0.94	0	0	258	99.23
0.94-0.95	0	0	258	99.23
0.95-0.96	0	0	258	99.23
0.96-0.97	0	0	258	99.23
0.97-0.98	0	0	258	99.23
0.98-0.99	0	0	258	99.23
0.99-1	0	0	258	99.23
1-1.01	0	0	258	99.23
1.01-1.02	0	0	258	99.23
1.02-1.03	0	0	258	99.23
1.03-1.04	1	0.38	259	99.62
1.04-1.05	0	0	259	99.62
1.05-1.06	0	0	259	99.62
1.06-1.07	0	0	259	99.62
1.07-1.08	1	0.38	260	100



BAT 22 (Cat. no. 125:4)

Data sheet

Fig 1-37.

1:1

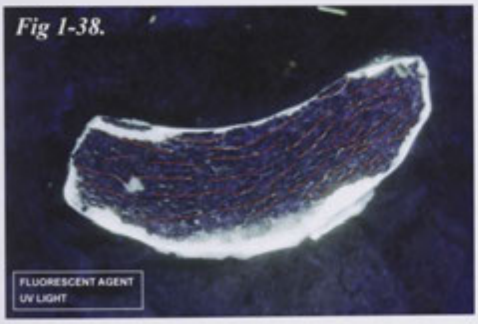


Fig 1-38.

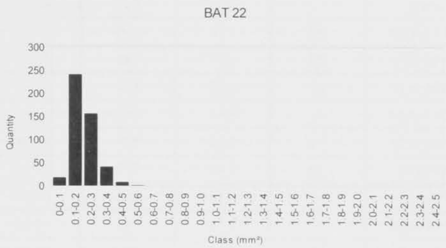
Fig 1-39.

Table 1-13. Temper data.

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
465			

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.02-0.03	0	0	0	0
0.03-0.04	0	0	0	0
0.04-0.05	0	0	0	0
0.05-0.06	1	0.21	1	0.21
0.06-0.07	1	0.21	2	0.43
0.07-0.08	4	0.86	6	1.28
0.08-0.09	5	1.07	11	2.36
0.09-0.1	7	1.5	18	3.85
0.1-0.11	10	2.14	28	6
0.11-0.12	23	4.93	51	10.92
0.12-0.13	13	2.78	64	13.7
0.13-0.14	31	6.64	95	20.34
0.14-0.15	24	5.14	119	25.48
0.15-0.16	29	6.21	148	31.69
0.16-0.17	19	4.07	167	35.76
0.17-0.18	38	8.14	205	43.9
0.18-0.19	24	5.14	229	49.04
0.19-0.2	30	6.42	259	55.46
0.2-0.21	27	5.78	286	61.24
0.21-0.22	27	5.78	313	67.02
0.22-0.23	13	2.78	326	69.81
0.23-0.24	24	5.14	350	74.95
0.24-0.25	20	4.28	370	79.23
0.25-0.26	11	2.36	381	81.58
0.26-0.27	11	2.36	392	83.94
0.27-0.28	8	1.71	400	85.65
0.28-0.29	6	1.28	406	86.94
0.29-0.3	9	1.93	415	88.87
0.3-0.31	11	2.36	426	91.22

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.31-0.32	3	0.64	429	91.86
0.32-0.33	2	0.43	431	92.29
0.33-0.34	4	0.86	435	93.15
0.34-0.35	3	0.64	438	93.79
0.35-0.36	2	0.43	440	94.22
0.36-0.37	5	1.07	445	95.29
0.37-0.38	1	0.21	446	95.5
0.38-0.39	4	0.86	450	96.36
0.39-0.4	6	1.28	456	97.64
0.4-0.41	1	0.21	457	97.86
0.41-0.42	3	0.64	460	98.5
0.42-0.43	1	0.21	461	98.72
0.43-0.44	1	0.21	462	98.93
0.44-0.45	0	0	462	98.93
0.45-0.46	0	0	462	98.93
0.46-0.47	1	0.21	463	99.14
0.47-0.48	0	0	463	99.14
0.48-0.49	0	0	463	99.14
0.49-0.5	1	0.21	464	99.36
0.5-0.51	0	0	464	99.36
0.51-0.52	0	0	464	99.36
0.52-0.53	0	0	464	99.36
0.53-0.54	0	0	464	99.36
0.54-0.55	0	0	464	99.36
0.55-0.56	1	0.21	465	99.57
0.56-0.57	0	0	465	99.57
0.57-0.58	0	0	465	99.57
0.58-0.59	0	0	465	99.57
0.59-0.6	0	0	465	99.57
0.6-0.61	0	0	465	99.57



BAT 25 (Cat. no. 100:8)

Data sheet

Fig 1-40.

1:1

Fig 1-41.

Table 1-14. Temper data.

Number of Objects	Area Fraction	Area (mm²)	Measured Area (mm²)
1145			

Class (mm²)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.02-0.03	0	0	0	0
0.03-0.04	0	0	0	0
0.04-0.05	3	0.26	3	0.26
0.05-0.06	10	0.87	13	1.14
0.06-0.07	30	2.62	43	3.76
0.07-0.08	38	3.32	81	7.07
0.08-0.09	61	5.33	142	12.4
0.09-0.1	73	6.38	215	18.78
0.1-0.11	87	7.6	302	26.38
0.11-0.12	102	8.91	404	35.28
0.12-0.13	107	9.34	511	44.63
0.13-0.14	96	8.38	607	53.01
0.14-0.15	98	8.56	705	61.57
0.15-0.16	70	6.11	775	67.69
0.16-0.17	60	5.24	835	72.93
0.17-0.18	48	4.19	883	77.12
0.18-0.19	47	4.1	930	81.22
0.19-0.2	39	3.41	969	84.63
0.2-0.21	31	2.71	1000	87.34
0.21-0.22	17	1.48	1017	88.82
0.22-0.23	17	1.48	1034	90.31
0.23-0.24	11	0.96	1045	91.27
0.24-0.25	11	0.96	1056	92.23
0.25-0.26	12	1.05	1068	93.28
0.26-0.27	16	1.4	1084	94.67
0.27-0.28	11	0.96	1095	95.63
0.28-0.29	3	0.26	1098	95.9
0.29-0.3	5	0.44	1103	96.33
0.3-0.31	4	0.35	1107	96.68
0.31-0.32	3	0.26	1110	96.94
0.32-0.33	5	0.44	1115	97.38
0.33-0.34	3	0.26	1118	97.64
0.34-0.35	6	0.52	1124	98.17
0.35-0.36	1	0.09	1125	98.25
0.36-0.37	0	0	1125	98.25
0.37-0.38	3	0.26	1128	98.52
0.38-0.39	2	0.17	1130	98.69
0.39-0.4	1	0.09	1131	98.78
0.4-0.41	3	0.26	1134	99.04
0.41-0.42	0	0	1134	99.04
0.42-0.43	0	0	1134	99.04
0.43-0.44	1	0.09	1135	99.13
0.44-0.45	2	0.17	1137	99.3
0.45-0.46	2	0.17	1139	99.48
0.46-0.47	2	0.17	1141	99.65
0.47-0.48	1	0.09	1142	99.74
0.48-0.49	0	0	1142	99.74
0.49-0.5	1	0.09	1143	99.83
0.62-0.63	1	0.09	1144	99.91
0.98-0.99	1	0.09	1145	100


BAT 25
Quantity
800
700
600
500
400
300
200
100
0
0-0.1
0.1-0.2
0.2-0.3
0.3-0.4
0.4-0.5
0.5-0.6
0.6-0.7
0.7-0.8
0.8-0.9
0.9-1.0
1.0-1.1
1.1-1.2
1.2-1.3
1.3-1.4
1.4-1.5
1.5-1.6
1.6-1.7
1.7-1.8
1.8-1.9
1.9-2.0
2.0-2.1
2.1-2.2
2.2-2.3
2.3-2.4
2.4-2.5
Class (mm²)

BAT 27 (Cat. no. 153:3)

Data sheet

Fig 1-42.

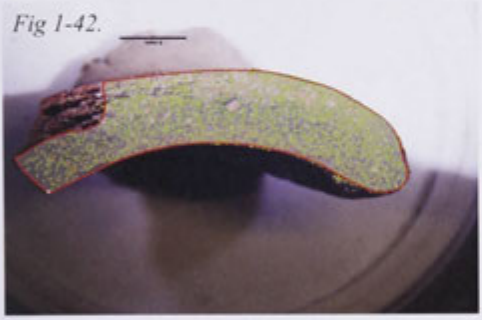


Fig 1-43.

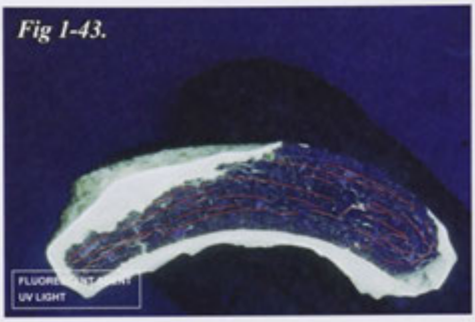


Table 1-15. Temper data.

Number of Objects	Area Fraction	Area (mm²)	Measured Area (mm²)
1202	0.337	193.59	960.05

Class (mm²)	Amount	Amount (%)	Cumulative	Cumulative (%)
0-0.1	35	2.91	35	2.91
0.1-0.2	270	22.46	305	25.37
0.2-0.3	403	33.53	708	58.9
0.3-0.4	207	17.22	915	76.12
0.4-0.5	105	8.74	1020	84.86
0.5-0.6	64	5.32	1084	90.18
0.6-0.7	44	3.66	1128	93.84
0.7-0.8	21	1.75	1149	95.59
0.8-0.9	18	1.5	1167	97.09
0.9-1.0	13	1.08	1180	98.17
1.0-1.1	8	0.67	1188	98.84
1.1-1.2	3	0.25	1191	99.08
1.2-1.3	2	0.17	1193	99.25
1.3-1.4	3	0.25	1196	99.5
1.4-1.5	2	0.17	1198	99.67
1.5-1.6	1	0.08	1199	99.75
1.6-1.7	0	0	1199	99.75
1.7-1.8	0	0	1199	99.75
1.8-1.9	0	0	1199	99.75
1.9-2.0	0	0	1199	99.75
2.0-2.1	2	0.17	1201	99.92
2.1-2.2	0	0	1201	99.92
2.2-2.3	0	0	1201	99.92
2.3-2.4	0	0	1201	99.92
2.4-2.5	0	0	1201	99.92
2.5-2.6	0	0	1201	99.92
2.6-2.7	0	0	1201	99.92
2.7-2.8	0	0	1201	99.92
2.8-2.9	0	0	1201	99.92
2.9-3.0	0	0	1201	99.92
3.0-3.1	0	0	1201	99.92
3.1-3.2	1	0.08	1202	100

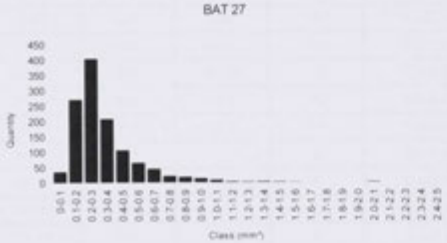


Fig 1-44. Max Feret Distribution.

BAT 28 (Cat. no. 137:5)

Data sheet

Table 1-16. Temper data

Number of Objects	Area Fraction	Area (mm²)	Measured Area (mm²)
454	0.34	73.33	424.84

Class (mm²)	Amount	Amount (%)	Cumulative	Cumulative (%)
0-0.1	44	9.69	44	9.69
0.1-0.2	40	8.81	84	18.5
0.2-0.3	158	34.8	242	53.3
0.3-0.4	104	22.91	346	76.21
0.4-0.5	47	10.35	393	86.56
0.5-0.6	25	5.51	418	92.07
0.6-0.7	13	2.86	431	94.93
0.7-0.8	5	1.1	436	96.04
0.8-0.9	6	1.32	442	97.36
0.9-1.0	5	1.1	447	98.46
1.0-1.1	3	0.66	450	99.12
1.1-1.2	1	0.22	451	99.34
1.2-1.3	0	0	451	99.34
1.3-1.4	1	0.22	452	99.56
1.4-1.5	0	0	452	99.56
1.5-1.6	1	0.22	453	99.78
1.6-1.7	1	0.22	454	100

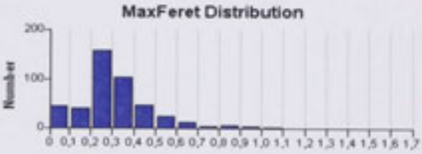


Fig 1-47. Max Feret Distribution.

BAT 29 (Cat. no. 119:2)

Data sheet


Fig 1-49.

Fig 1-50.

Table 1-17. Temper data.

Number of Objects	Area Fraction	Area (mm²)	Measured Area (mm²)
947	0.24	75.23	N/A

Class (mm²)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.0-0.1	260	27.46	260	27.46
0.1-0.2	313	33.05	573	60.51
0.2-0.3	210	22.18	783	82.68
0.3-0.4	103	10.88	886	93.56
0.4-0.5	34	3.59	920	97.15
0.5-0.6	12	1.27	932	98.42
0.6-0.7	9	0.95	941	99.37
0.7-0.8	4	0.42	945	99.79
0.8-0.9	1	0.11	946	99.89
0.9-1.0	0	0	946	99.89
1.0-1.1	1	0.11	947	100

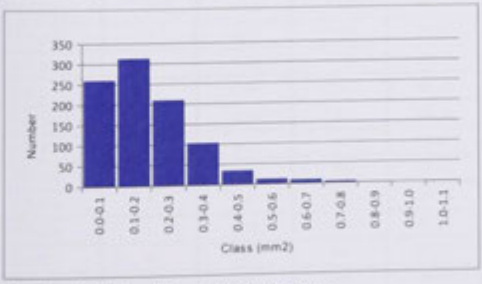


Fig 1-48. Max Feret Distribution.

BAT 30 (Cat. no. 117:3)

Data sheet

Table 1-18. Temper data.

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
1235			

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0-0.1	201	16.28	201	16.28
0.1-0.2	293	23.72	494	40
0.2-0.3	250	20.24	744	60.24
0.3-0.4	232	18.79	976	79.03
0.4-0.5	136	11.01	1112	90.04
0.5-0.6	65	5.26	1177	95.3
0.6-0.7	28	2.27	1205	97.57
0.7-0.8	16	1.3	1221	98.87
0.8-0.9	8	0.65	1229	99.51
0.9-1.0	3	0.24	1232	99.76
1.0-1.1	1	0.08	1233	99.84
1.1-1.2	2	0.16	1235	100

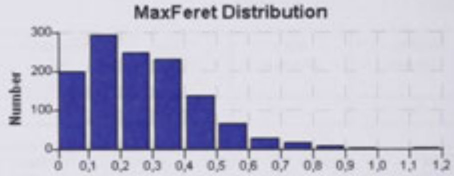


Fig 1-53. Max Feret Distribution.

BAT 32 (Cat. no. 91:2)

Data sheet

Fig 1-54.

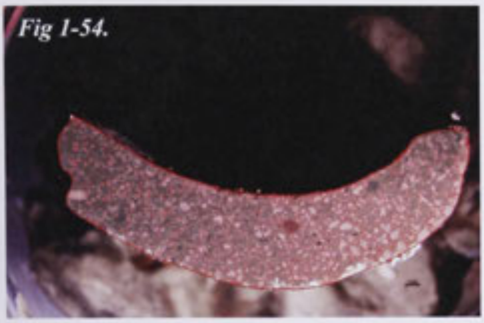


Fig 1-55.

Table 1-19. Temper data.

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
786	0.523	139.38	666.7

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0-0.1	281	35.75	281	35.75
0.1-0.2	147	18.7	428	54.45
0.2-0.3	142	18.07	570	72.52
0.3-0.4	86	10.94	656	83.46
0.4-0.5	41	5.22	697	88.68
0.5-0.6	31	3.94	728	92.62
0.6-0.7	18	2.29	746	94.91
0.7-0.8	8	1.02	754	95.93
0.8-0.9	5	0.64	759	96.56
0.9-1.0	3	0.38	762	96.95
1.0-1.1	3	0.38	765	97.33
1.1-1.2	3	0.38	768	97.71
1.2-1.3	2	0.25	770	97.96
1.3-1.4	3	0.38	773	98.35
1.4-1.5	3	0.38	776	98.73
1.5-1.6	5	0.64	781	99.36
1.6-1.7	1	0.13	782	99.49
1.7-1.8	0	0	782	99.49
1.8-1.9	0	0	782	99.49
1.9-2.0	1	0.13	783	99.62
2.0-2.1	0	0	783	99.62
2.1-2.2	0	0	783	99.62
2.2-2.3	1	0.13	784	99.75

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
...				
3.3-3.4	1	0.13	785	99.87
...				
17.6-17.7	1	0.13	786	100

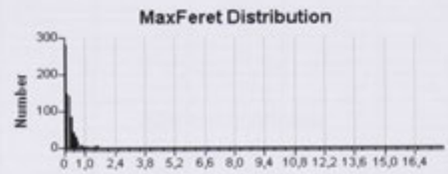


Fig 1-56. Max Feret Distribution.

BAT 33 (Cat. no. 76:5)

Data sheet

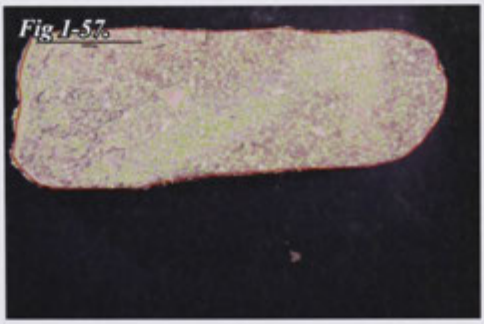


Fig 1-57.

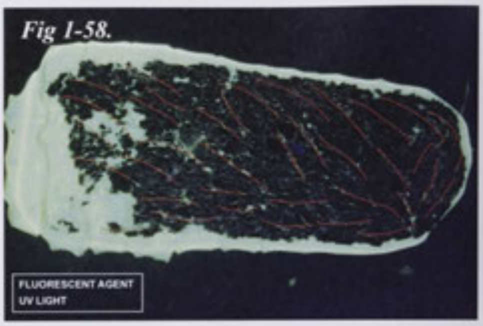


Fig 1-58.

Table 1-20. Temper data.

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
2201	0.199	596.32	1510.13

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.1-0.2	638	28.99	638	28.99
0.2-0.3	634	28.81	1272	57.79
0.3-0.4	418	18.99	1690	76.78
0.4-0.5	207	9.4	1897	86.19
0.5-0.6	107	4.86	2004	91.05
0.6-0.7	62	2.82	2066	93.87
0.7-0.8	42	1.91	2108	95.77
0.8-0.9	32	1.45	2140	97.23
0.9-1.0	21	0.95	2161	98.18
1.0-1.1	14	0.64	2175	98.82
1.1-1.2	6	0.27	2181	99.09
1.2-1.3	5	0.23	2186	99.32
1.3-1.4	5	0.23	2191	99.55
1.4-1.5	1	0.05	2192	99.59
1.5-1.6	3	0.14	2195	99.73
1.6-1.7	1	0.05	2196	99.77
1.7-1.8	0	0	2196	99.77
1.8-1.9	2	0.09	2198	99.86
1.9-2.0	1	0.05	2199	99.91
2.0-2.1	0	0	2199	99.91
2.1-2.2	0	0	2199	99.91
2.2-2.3	0	0	2199	99.91
2.3-2.4	0	0	2199	99.91
2.4-2.5	0	0	2199	99.91
2.5-2.6	0	0	2199	99.91
2.6-2.7	0	0	2199	99.91
2.7-2.8	0	0	2199	99.91
2.8-2.9	0	0	2199	99.91
2.9-3.0	1	0.05	2200	99.95
3.0-3.1	0	0	2200	99.95
3.1-3.2	0	0	2200	99.95
3.2-3.3	0	0	2200	99.95
3.3-3.4	0	0	2200	99.95
3.4-3.5	0	0	2200	99.95
3.5-3.6	0	0	2200	99.95
3.6-3.7	0	0	2200	99.95
3.7-3.8	1	0.05	2201	100

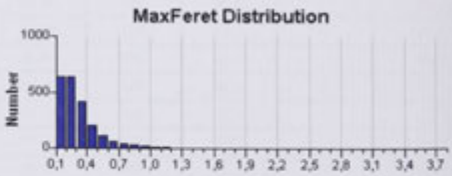


Fig 1-59. Max Feret Distribution.

BAT 34 (Cat. no. 62:1)

Data sheet

Fig 1-60.

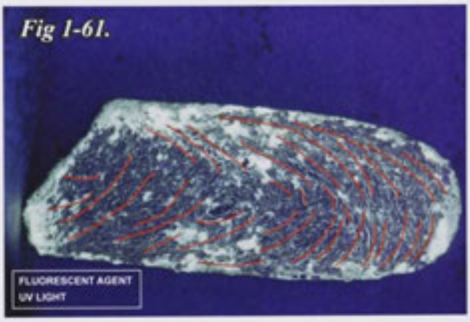


Fig 1-61.

Table 1-21. Temper data.

Number of Objects	Area Fraction	Area (mm²)	Measured Area (mm²)
2428	0.361	743.06	2114.77

Class (mm²)	Amount	Amount (%)	Cumulative	Cumulative (%)
0-0.1	93	3.83	93	3.83
0.1-0.2	340	14	433	17.83
0.2-0.3	498	20.51	931	38.34
0.3-0.4	484	19.93	1415	58.28
0.4-0.5	349	14.37	1764	72.65
0.5-0.6	205	8.44	1969	81.1
0.6-0.7	118	4.86	2087	85.96
0.7-0.8	99	4.08	2186	90.03
0.8-0.9	59	2.43	2245	92.46
0.9-1.0	48	1.98	2293	94.44
1.0-1.1	35	1.44	2328	95.88
1.1-1.2	22	0.91	2350	96.79
1.2-1.3	14	0.58	2364	97.36
1.3-1.4	11	0.45	2375	97.82
1.4-1.5	13	0.54	2388	98.35
1.5-1.6	11	0.45	2399	98.81
1.6-1.7	6	0.25	2405	99.05
1.7-1.8	1	0.04	2406	99.09
1.8-1.9	2	0.08	2408	99.18
1.9-2.0	3	0.12	2411	99.3
2.0-2.1	4	0.16	2415	99.46
2.1-2.2	1	0.04	2416	99.51
2.2-2.3	1	0.04	2417	99.55
2.3-2.4	3	0.12	2420	99.67
2.4-2.5	2	0.08	2422	99.75
2.7-2.8	1	0.04	2423	99.79
2.9-3.0	1	0.04	2424	99.84
3.1-3.2	1	0.04	2425	99.88
3.6-3.7	1	0.04	2426	99.92
4.4-4.5	1	0.04	2427	99.96
4.7-4.8	1	0.04	2428	100

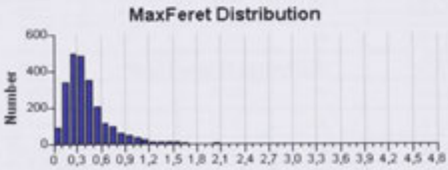


Fig 1-62. Max Feret Distribution.

BAT 35 (Cat. no. 42:2)

Data sheet

Fig 1-63.

Table 1-22. Temper data

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
478	0.303	205.12	666.7

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0-0.1	11	2.3	11	2.3
0.1-0.2	75	15.69	86	17.99
0.2-0.3	99	20.71	185	38.7
0.3-0.4	83	17.36	268	56.07
0.4-0.5	80	16.74	348	72.8
0.5-0.6	38	7.95	386	80.75
0.6-0.7	29	6.07	415	86.82
0.7-0.8	16	3.35	431	90.17
0.8-0.9	12	2.51	443	92.68
0.9-1.0	7	1.46	450	94.14
1.0-1.1	4	0.84	454	94.98
1.1-1.2	7	1.46	461	96.44
1.2-1.3	4	0.84	465	97.28
1.3-1.4	3	0.63	468	97.91
1.4-1.5	1	0.21	469	98.12
1.5-1.6	2	0.42	471	98.54
1.6-1.7	0	0	471	98.54
1.7-1.8	3	0.63	474	99.16
1.8-1.9	0	0	474	99.16
1.9-2.0	1	0.21	475	99.37
2.0-2.1	2	0.42	477	99.79
2.1-2.2	0	0	477	99.79
2.2-2.3	0	0	477	99.79
2.3-2.4	0	0	477	99.79
2.4-2.5	1	0.21	478	100

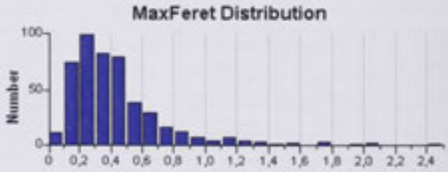


Fig 1-64. Max Feret Distribution.

BAT 36 (Cat. no. 3:1)

Data sheet

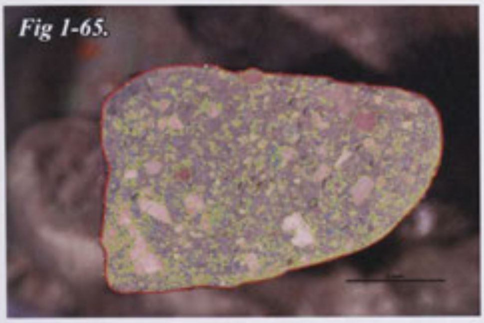


Fig 1-65.

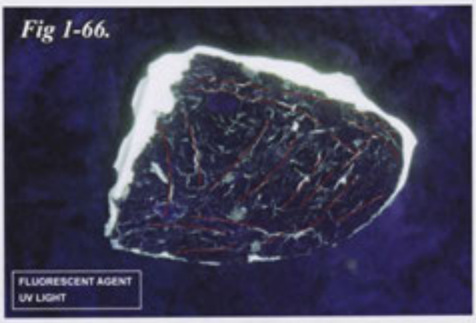


Fig 1-66.

Table 1-23. Temper data

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
1192	0.323	177.93	424.84

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0-0.1	548	45.97	548	45.97
0.1-0.2	240	20.13	788	66.11
0.2-0.3	149	12.5	937	78.61
0.3-0.4	92	7.72	1029	86.33
0.4-0.5	51	4.28	1080	90.6
0.5-0.6	36	3.02	1116	93.62
0.6-0.7	17	1.43	1133	95.05
0.7-0.8	11	0.92	1144	95.97
0.8-0.9	15	1.26	1159	97.23
0.9-1.0	7	0.59	1166	97.82
1.0-1.1	3	0.25	1169	98.07
1.1-1.2	5	0.42	1174	98.49
1.2-1.3	5	0.42	1179	98.91
1.3-1.4	4	0.34	1183	99.24
1.4-1.5	0	0	1183	99.24
1.5-1.6	1	0.08	1184	99.33
1.6-1.7	2	0.17	1186	99.5
1.7-1.8	0	0	1186	99.5
1.8-1.9	1	0.08	1187	99.58
1.9-2.0	0	0	1187	99.58
2.0-2.1	0	0	1187	99.58
2.1-2.2	2	0.17	1189	99.75
2.2-2.3	0	0	1189	99.75
2.3-2.4	1	0.08	1190	99.83
2.4-2.5	0	0	1190	99.83
2.5-2.6	0	0	1190	99.83
2.6-2.7	0	0	1190	99.83
2.7-2.8	0	0	1190	99.83
2.8-2.9	0	0	1190	99.83
2.9-3.0	0	0	1190	99.83
3.0-3.1	1	0.08	1191	99.92
...				
4.0-4.1	1	0.08	1192	100

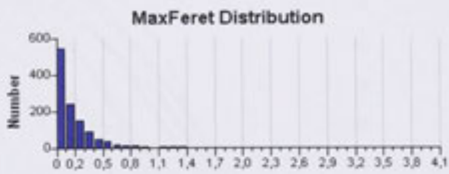


Fig 1-67. Max Feret Distribution.

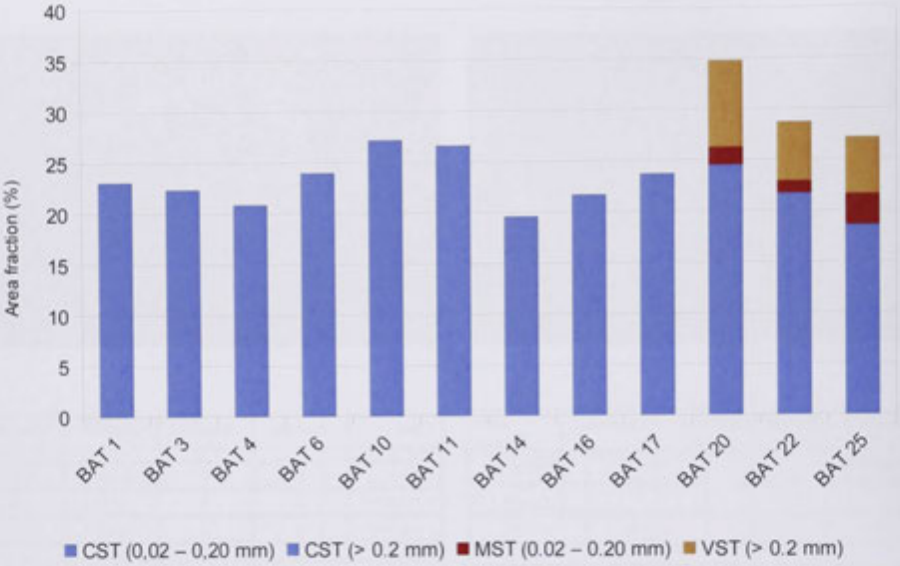


Fig 1-68. Amount of temper in the clay.

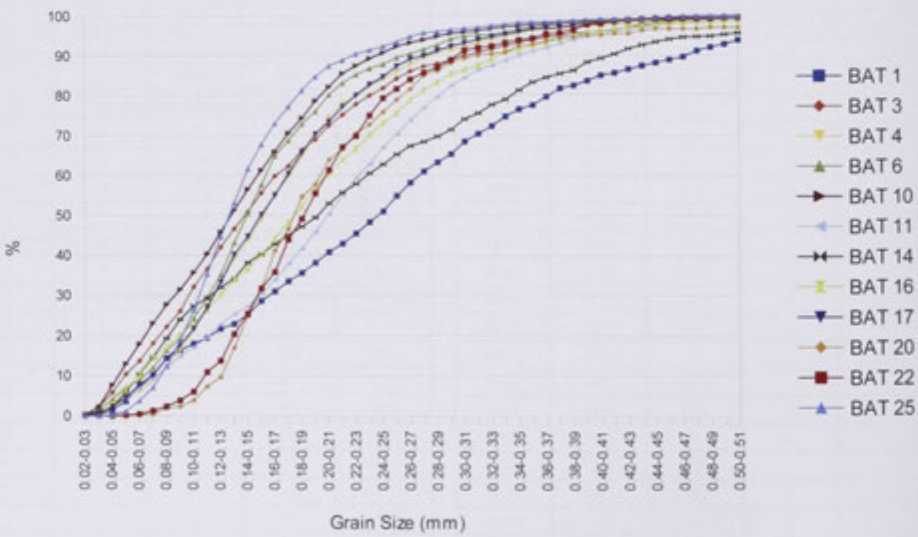


Fig 1-69. Cumulative grain size distribution. Samples BAT 1 - 25.

Table 1-24. Result of pore line analysis..

Lab. no.	Cat. no	Maufacturing technique
BAT 1	176:8	Paddle and anvil
BAT 3	172:21	Paddle and anvil
BAT 4	170:1	Paddle and anvil
BAT 6	170:2	Paddle and anvil
BAT 10	160:3	Paddle and anvil
BAT 11	159:3	Paddle and anvil
BAT 14	159:1	Paddle and anvil
BAT 16	145:2	Paddle and anvil
BAT 17	143:1	Paddle and anvil
BAT 20	129:2	Paddle and anvil
BAT 22	125:4	Paddle and anvil
BAT 25	100:8	N/A
BAT 27	153:3	Paddle and anvil
BAT 28	137:5	Paddle and anvil
BAT 29	119:2	Coiling/Paddle and anvil
BAT 30	117:3	Paddle and anvil
BAT 31	100:12	Paddle and anvil
BAT 32	91:2	Coiling
BAT 33	76:5	Coiling
BAT 34	62:1	Inconclusive
BAT 35	42:2	Inconclusive
BAT 36	3:1	Coiling

Table 1-25. Thermal test results.

Cat. no.	Temperature (°C)	20	100	200	300	400	500	600	700	800	900	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500
14	Hue	4		4	4	4	4	4	4	4	2	2	2	2	2	2						
	Value	4		4	4	4	5	7	4	4	7	8	8	8	8	3						
	Chroma	2		2	2	2	3	4	4	2	4	4	4	4	3	2						
	Phase									F						B	S					
92	Hue	3		3	3	3	3	3	3	2	2	2	2	2	2	3						
	Value	7		6	6	6	6	7	7	7	7	7	7	7	6	6						
	Chroma	6		6	6	4	4	4	4	6	6	8	6	6	6	6						
	Phase								F	F							S					
109	Hue	1		1	1	1	2	1	1	1	1	1	1	1	1	1	2					
	Value	4		4	4	3	7	4	5	6	5	5	5	5	5	4	3					
	Chroma	4		4	2	2	6	4	4	4	4	4	4	4	4	2	2					
	Phase							F	X								B	S				
110	Hue	2		2	2	2	2	2	2	2	2	2										
	Value	4		4	5	5	5	5	4	6	6	5										
	Chroma	6		6	6	4	6	6	6	6	6	6										
	Phase								F				X									
159	Hue	1		1	1	1	1	1	1	1	1	1	1	1	1	1						
	Value	4		4	4	4	4	4	5	5	5	4	4	4	5	4						
	Chroma	4		4	4	4	5	4	6	6	6	4	4	3	4	4						
	Phase								X	F							S					
176	Hue	1		1	1	1	1	1	1	1	1	1	1	1	1	1	2					
	Value	5		5	5	5	5	5	5	5	5	5	4	4	4	4	3					
	Chroma	8		8	4	6	6	8	8	8	8	6	6	6	6	4	1					
	Phase							F	F	X								S				
Feature K	Hue	1		1	1	1	1	1	1	1	1	1										
	Value	3		3	4	4	4	4	3	4	4	4										
	Chroma	6		6	4	4	4	4	6	4	6	6										
	Phase								F				X									

D = Dilation
S = Sintering
F = Fluid

F = Firing temperature

Relations of Sand Tempers in Prehistoric Sherds from Unai Bapot on Saipan

Petrographic Report WRD-285 (15 June 2010)

Thin sections of twenty potsherds sent by Geoffrey Clark at ANU from the prehistoric site of Unai Bapot on the north shore of Lau Lau Bay on southeast Saipan were studied petrographically in thin section to establish the nature of the sand tempers in the sherds and to make comparisons with tempers in other prehistoric Saipan wares (Dickinson et al., 2001; Dickinson, 2006, p. 40-44). The sherds were selected as representative of the range of tempers and ceramic styles that are present in the ANU Unai Bapot collection. Five Unai Bapot sherds examined five years ago for Mike T. Carson of IARII were included with the ANU Unai Bapot sherds for the present study. Table 285-1 indicates the provenience and temper groupings of all the 25 sherds examined in thin section.

A placer beach sand collected by Geoffrey Clark or Olaf Winter from the beach face in front of the site closely resembles a placer beach sand collected by me from the fairweather berm crest of the beach along the north shore of Lau Lau Bay not far east of the Unai Bapot site (Dickinson et al., 2001, beach sand sample SAI-1 of Table I). Both sands are composed dominantly of well sorted opaque iron oxide grains (probably mainly magnetite) with minor admixture of pyroxene mineral grains, and do not resemble any of the sherd tempers. The composition of the sands is appropriate for derivation by placering of detritus sourced in the andesitic Hagman Formation exposed on steep slopes northwest of Lau Lau Bay (Cloud et al., 1956), but local placer sands were clearly not used as temper for any wares of the Unai Bapot ceramic assemblage.

Unai Bapot Sherd Tempers

A majority (~55%) of the Unai Bapot sherds contain as temper fine and well sorted hybrid sand (Table 285-1A) composed dominantly of calcareous grains with minor admixtures of terrigenous grains among which quartz is consistently prominent as an indication of derivation from dacitic volcanic sources in central Saipan. The hybrid temper sands are coastal beach sands collected somewhere on Saipan. The presence of quartz is diagnostic in the Mariana Islands of origin on Saipan for either modern sands or sherd tempers because quartz simply does not occur in the volcanic assemblages of the other islands (Dickinson *et al.*, 2001; Dickinson, 2006, p. 41-42). Two other subordinate temper types each occur in 20%-25% of the Unai Bapot sherds (Table 285-1BC): (a) nearly quartz-free andesitic temper sand in which the presence of orthopyroxene as well as clinopyroxene is also diagnostic of origin on Saipan, and (b) hybrid quartzose-calcareous hybrid sand in which the abundance of quartz is again diagnostic of origin from somewhere on Saipan.

The three temper types are different enough to make collection from the same exact locality implausible, although distances between the temper sources on an island the size of Saipan need not have been great. Possible origins for the tempers are discussed after each is described, but it is worthy of note that all the sherds of crude coarse ware contain Type B andesitic temper, with one of the other two more closely related temper types present in all the redware sherds. The tentative distinction in Table 285-1 between thin and thick redware is probably dysfunctional because there are no apparent temper distinctions between the two. Perhaps the sherds of thin and thick redware came from different parts of similar vessels or from different kinds of related vessels made in the same place or places. Sherds of crude coarse ware derive in every case from shallower parts of excavations in various site units, suggesting a temporal distinction between older redware and younger coarse ware made either in different places or using different temper sands.

Type A Calcareous Hybrid Temper

Fourteen redware sherds with dominantly (≥90%) calcareous temper (Type A of Table 285-1) contain terrigenous grains of quartz, feldspar, and felsite (silicic volcanic rock fragments) in variable proportions, together with minor pyroxene heavy mineral grains. Net percentages of terrigenous grain types (Table 285-2) reflect derivation from dacitic bedrock exposed on Saipan but nowhere else within the Mariana Islands (Dickinson et al., 2001; Dickinson, 2006, p. 41).

Care must be taken interpreting the origins of hybrid tempers (mixed terrigenous and calcareous grains) from Saipan because some stream sands are known to be hybrid aggregates (Table V of Dickinson et al., 2001) in which the calcareous grains are reworked limeclasts derived from the widespread Neogene limestone bedrock of Saipan (Cloud et al., 1956). Detrital limeclasts can be detected, however, because they are composed in whole or in part of diagenetic microspar that is more coarsely crystalline than the micrite of pelletal and algal origin in calcareous sand derived from modern reef tracts. Moreover, calcareous grains (limeclasts) are subordinate in abundance to terrigenous grains in hybrid Saipan stream sands and derivative tempers, whereas calcareous grains are dominant in Unai Bapot Type A (and Type C) tempers. Calcareous grains in the Type A tempers of Unai Bapot sherds are interpreted as modern reef detritus rather than limeclasts, and the temper sands are therefore interpreted as coastal beach sands, based on the internal textures of the calcareous grains, some of which are skeletal debris, the predominance of the calcareous grains over terrigenous grains, and the generally good sorting and rounding of the grain aggregates. Minor contributions of detrital limeclasts to the Type A Unai Bapot tempers cannot be wholly excluded, but the dominant calcareous grains appear to be modern reef debris.

The terrigenous fraction of the dominant hybrid tempers (Type A) is distinctly less quartzose than in sherds examined previously from Unai Achugao and Chalan Piao on the west coast of Saipan (Table VI of Dickinson et al., 2001). The latter derive from the northern and southern extremities of the calcareous ("white sand") beach system developed along the leeward side of Saipan, and can therefore be regarded jointly as representative of the beach sand tempers to be expected for sites along the western shores of Saipan. The compositional contrast is shown by the ratio Q-F-R (quartz grains-feldpar grains-felsitic volcanic rock fragments). That ratio is 27-25-47 for Unai Bapot sherds (Table 285-4) but averages 95-2-3 for the west coast sherds.

Although derivation from elsewhere on Saipan, apart from the west coast, is strongly indicated for the Type A hybrid Unai Bapot tempers, their actual origin is difficult to infer. Dacitic sources on Saipan are exposed only in the uplands of central Saipan east of Tanapag (Cloud et al., 1956), and the restricted distribution of dacitic bedrock makes a source for the hybrid Type A tempers on either southern or northern Saipan difficult to envision. Yet beach deposits are less extensive on the east coast than on the west or south coasts of Saipan. Perhaps the most attractive potential collecting site is the coast near Puntan Halaihai where southward longshore drift under the influence of the prevailing trade winds could pile up hybrid beach sand against the barrier of the Puntan Lau Lau–Puntan Hagman headland. As Puntan Halaihai is only 3 km from Unai Bapot across a broad coastal plateau <100 m in maximum elevation, it seems conceivable that Unai Bapot potters could have visited Puntan Halaihai to collect temper sand (alternately, a canoe voyage of ~5 km could access the beach faces near Puntan Halaihai). Wholesale ceramic transfer of the dominant fraction of the Unai Bapot ceramic suite from elsewhere is conceivable, but is perhaps a less attractive inference than use of nonlocal temper in a local Unai Bapot ceramic industry. An alternate possibility is that non-placer beach sand on the beach face in front of the Unai Bapot site might have the composition of Type A temper, but this alternative seems less likely than a Puntan Halaihai origin of the temper because no dacitic sources are exposed in the catchment of Lau Lau Bay, and the bay is shielded from longshore drift of potentially dacitic hybrid sand contributed to the east coast farther north by the Puntan Lau Lau–Puntan Hagman headland.

Type B Andesitic Temper

The temper sands in six sherds of crude coarse ware contain exclusively terrigenous volcanic sands as temper (Type B). All are poorly to moderately sorted aggregates of grain types derived mainly or exclusively from andesitic sources (Table 285-3), and probably collected as inland sands from streams, ravines, or slopewash aprons. Three-quarters or more (up to 90%) of the temper grains are plagioclase feldspar mineral grains or volcanic rock fragments in subequal proportions, with the latter displaying a variety of internal textures and fabrics suggesting derivation from multiple andesitic source rocks rather than a single parent rock of local or restricted distribution. The variation in relative proportions of microlitic and vitric grains is not significant, however, because the plagioclase microlites have grown in volcanic glass to form hyalopilitic internal grain textures, and microlitic to vitric grains form a gradational spectrum. Variations in the proportions of heavy minerals (opaques and pyroxenes) merely reflect slight variations in the degree of placering each sand experienced during deposition. Subordinate pyroxene grains include both clinopyroxene (augite) and orthopyroxene (hypersthene) in the net overall ratio of 3:1, which is within the range noted previously for other andesitic temper sands from Saipan (Table VII of Dickinson et al., 2001). Orthopyroxene is not known, however, to occur in the temper sands of any wares made on Guam or Rota, and seems a reliable guide to Mariana andesitic tempers from Saipan.

The andesitic Hagman Formation is exposed on slopes rising above the Unai Bapot site on Lau Lau Bay, on the Puntan Hagman headland 3 km east of Unai Bapot, and in the southern reaches of the central pre-limestone uplands 6 km north of Unai Bapot. A choice among those three areas for the source of the andesitic tempers in Unai Bapot sherds seems almost impossible to make. The presence of minor quartz grains and felsitic volcanic rock fragments in the temper sands may, however, suggest minor contributions from dacitic volcaniclastic strata of the Densinyama Formation, which is associated with exposures of Hagman Formation on Puntan Hagman and to the north of Unai Bapot (southeast of Tanapag), but not on slopes rising directly above the Unai Bapot site. Percentages of quartz in the Type B tempers are quite low (≤1%) and contributions from dacitic bedrock to the predominantly andesitic sands may not be required to explain its occurrence, in which case derivation of andesitic temper sand from slopes in the immediate vicinity of Unai Bapot is a clear possibility. Regardless of the origin of the temper sand (local or non-local), it is impossible to judge from petrographic criteria between the ceramic transfer of finished ware from elsewhere to Unai Bapot and the procurement of temper sand from elsewhere to support ceramic manufacture at Unai Bapot. In either case, the stratigraphic distribution of the crude coarse ware containing andesitic temper suggests that tempering practices or patterns of ceramic transfer changed from an early redware ceramic phase during which hybrid tempers were characteristic to a later phase during which wholly terrigenous temper was characteristic.

Type C Quartzose Hybrid Temper

The Type C hybrid temper of selected redware sherds differs in several respects from the Type A hybrid temper present in three times as many redware sherds. Type C temper is coarser grained and less well sorted than Type A temper, and contains a higher proportion of terrigenous grains that are much more quartzose (Table 285-4). The calcareous grains of Type C temper are also, however, micritic and skeletal grains of modern reef debris, and the two hybrid tempers can be interpreted with confidence as coastal sands derived form different localities on Saipan. The quartzose character of Type C temper implies derivation of its terrigenous sand component from either dacitic bedrock (Sankakuyama Formation) or derivative volcaniclastic strata (Densinyama Formation) of the uplands in central Saipan east of Tanapag (Cloud et al., 1956).

Texturally and in generic relation to the derivation of its terrigenous component from dacitic sources, Unai Bapot Type C temper resembles the storm deposits (Qr of Cloud et al. 1956) on coastal terraces near Unai Fahang along the east coast of Saipan (sand sample SAI-2 of Table I in Dickinson et al., 2001). Although the single sample of the terrace sand studied previously does not compositionally match Unai Bapot Type C temper at all closely (Table VI of Dickinson et al., 2001), it is nevertheless attractive to suppose that Type C temper may have been collected from the surfaces of discontinuous coastal terraces that extend along the east coast of Saipan from Puntan Nanasu on the north to Puntan Halaihai on the south near the beaches where Unai Bapot Type A temper may have been collected. The only available sample (SAI-2) of the terrace sand was collected near Unai Fahang near the northernmost extremity of the elongate terrace remnants, and may not be representative of terrace sands present farther south. Close proximity of collecting sites for Unai Bapot Type A and Type C temper sands is perhaps favored by their joint occurrence, seemingly interchangeably, in redware sherds from Unai Bapot.

Temper Relations

There is no indication from temper analysis that any Unai Bapot sherds reflect ceramic transfer from the west coast of Saipan, although sherds of that apparent origin have been detected at archaeological sites on Tinian and Rota (Table VI of Dickinson et al., 2001). Instead, the three temper types present in Unai Bapot sherds can plausibly be traced to potential sources on or near the east coast of Saipan within just a few kilometers of the Unai Bapot site. Perhaps the most attractive scenario for Unai Bapot ceramics is fabrication of older redware using hybrid beach and terrace sands from near Puntan Halaihai to the northeast of Lau Lau Bay as temper, and of younger and cruder coarse ware using andesitic temper sand collected from ravines immediately upslope from the Unai Bapot site itself. The reason for the wholesale shift in tempering practice is not apparent from petrographic analysis, nor can petrographic analysis distinguish between possibly non-local wares and local wares made using non-local tempers.

References Cited

Cloud, P.E., Jr., Schmidt, R.G., and Burke, H.W., 1956, Geology of Saipan, Mariana Islands; Part 1. General geology. Washington, D.C., U.S. Geological Survey Professional Paper 280–A, 126 pp.

Dickinson, W.R., 2006. Temper Sands in Prehistoric Oceanian Pottery: Geotectonics, Sedimentology, Petrography, Provenance. Boulder, Colorado, Geological Society of America Special Paper 406, 164 pp.

Dickinson, W.R., Butler, B.M., Moore, D.E., and Swift, M., 2001. Geologic sources and geographic distribution of sand tempers in prehistoric potsherds from the Mariana islands. Geoarchaeology 16:827-854.

Table 285-1: Temper Types, Provenience, and Ceramic Style of Unai Bapot Sherds (BP- prefix denotes ANU sherds; UB- prefix denotes IARII sherds).

Unai Bapot Type A Temper: mixed dacitic (quartz-bearing)-calcareous hybrid temper sand

Sherd	Cat. No.	Unit	Depth (cm)	Ceramic Style	Comment
BP-2	162	2	230-240	Thick red ware	gc-temp
BP-3	Feature K		245-275	Thin red ware rim sherd	
BP-7	91	3	140-150	Thick red ware	
BP-8	155	2	220-230	Thick red ware	
BP-10	122	2	180-190	Thin red ware	
BP-11	172	5	240-250	Thin red ware rim sherd	
BP-13	129	1	190-200	Thin red ware	Block A, 14/4/8
BP-14	92	4	140-150	Decorated rim	Block A , 4/10/8
BP-15	92	4	140-150	Decorated	Block A
BP-17	162	2	230-240	Thin red ware rim sherd	gc-temp
BP-18	162	2	230-240	Thin red ware	
UB-90-1*	90			Thin ware	
UB-93-1*	93			Thin ware	
UB-95-1*	95			Thin ware	

*) One of a subset of five thin sherds with fine calcareous or hybrid temper.

Unai Bapot Type B Temper: terrigenous andesitic (non-quartzose) volcanic sand temper

Sherd	Cat. No.	Unit	Depth	Ceramic Style	Comment
BP-1	21	3	49-65	Crude coarse ware	
BP-4	10	1	35-49	Crude coarse ware	
BP-6	131	3	90-100	Crude coarse ware	5/4/8
BP-9	90	2	140-150	Crude coarse ware	
BP-12	62	8	100-110	Crude coarse ware	
UB-77-1*				Crude coarse ware	

*) One of five sherds of crude coarse ware with exclusively terrigenous temper.

Unai Bapot Type C Temper: mixed quartzose (dacitic)-calcareous hybrid temper sand

Sherd	Cat. No.	Unit	Depth	Ceramic Style	Comment
BP-5	165	2	240-250	Thin red ware	
BP-16	83	3	130-140	Decorated	9/4/8
BP-19	145	8	200-210	Thin red ware	
BP-20	165	2	240-250	Thick red ware	
UB-82-1*				Crude coarse ware	

*) One of five sherds of crude coarse ware (cat #82) with calcareous or hybrid temper.

Table 285-2: Terrigenous grain types present in largely calcareous Type A temper of Unai Bapot sherds from a census of non-calcareous and non-opaque terrigenous grains in each sherd thin section (tempers are 90%-95% calcareous grains and 1%-4% opaque grains).

Sherd	**Quartz**	**Feldspar**	**Felsite**	**Clinopyroxene**	**Orthopyroxene**
BP-2	23	13	11	-	-
BP-3	9	5	15	-	-
BP-7	2	5	18	5	1
BP-8	22	18	35	4	1
BP-10	1	6	10	2	-
BP-11	11	12	4	-	-
BP-13	10	9	26	-	-
BP-14	9	7	2	-	-
BP-15	5	7	-	-	-
BP-17	12	10	43	-	-
BP-18	5	6	13	-	-
UB-90-1	3	4	7	4	-
UB-93-1	7	9	18	4	-
UB-95-1	3	2	6	-	-
Total	122	113	208	19	2
Net %	26	24	45	4	Tr

Table 285-3. Frequency percentages of grain types in Type B andesitic temper sands of Unai Bapot sherds based on crosshair traverse counts of n grains in thin section.

Grain Type	**BP-1**	**BP-4**	**BP-6**	**BP-9**	**BP-12**	**Mean**	**Ub-77-1**
(n)	(220)	(210)	(250)	(230)	(165)	Bp (n=5)	(240)
Quartz	-	1	-	1	1	1	1
Plagioclase	46	44	47	45	35	43±4	25
Clinopyroxene	4	13	12	11	6	9±4	3
Orthopyroxene	Tr	3	4	4	2	3±1	1
Opaque	5	7	4	5	10	6±2	11
Microlitic Vrf	21	8	17	20	16	16±5	17
Felsitic Vrf	5	4	5	7	7	6±1	10
Vitric Vrf	19	20	11	8	23	16±6	32
(Total Vrf)	(45)	(32)	(33)	(35)	(46)	(38±6)	(59)

Table 285-4. Terrigenous grain types present in largely calcareous Type C temper of Unai Bapot sherds from a census of non-calcareous and non-opaque terrigenous grains in each sherd thin section (tempers are 70%-85% calcareous grains and 2%-8% opaque grains).

Grain Type	BP-5	BP-16	BP-19	BP-20	UB-82-1	Total	Net %
Quartz	38	39	55	40	50	222	70%
Plagioclase	9	8	24	14	25	80	25%
Felsite	2	7	1	2	4	16	5%

Temper Sand in an Additional Sherd from Unai Bapot on Saipan

Petrographic Report WRD-287 (8 September 2010)

An additional sherd (BP-21 but thin section labeled BPX by WRD), decorated with "dentate stamping and line incising" was sent by Geoffrey Clark for temper comparison with the other Unai Bapot sherds studied previously (Petro Rpt WRD-285 of 15 June 2010). The extra Unai Bapot sherd contains a dominantly calcareous temper sand containing <10% terrigenous grains.

The temper is indistinguishable both texturally and compositionally from temper sands in at least five of the other Unai Bapot sherds (BP-2, BP-10, BP-13, BP-17, BP-18) containing Type A hybrid temper sands dominant in Unai Bapot sherds, and thought provisionally to derive from beaches near Puntan Halaihai on the east coast of Saipan. The temper sand is quite distinctive visually from the hybrid tempers in Chalan Piao sherds from the west coast of Saipan containing clear limpid quartz grains as their most prominent terrigenous grain type.

The close similarity of the terrigenous fraction of grains in the additional Unai Bapot sherd to the terrigenous fractions of grains in the other five Unai Bapot sherds noted above is clear from the following grain statistics derived from counts of individual temper grains (numbers of grains in each case with percentages in parentheses):

Grain Type	Extra Unai Bapot Sherd (BP-21 or BPX)	Five Unai Bapot Sherds (BP-2, 10, 13, 17, 18)
Quartz	11 (25%)	51 (26%)
Feldspar	7 (16%)	49 (22%)
Felsite	25 (57%)	103 (52%)

Fig 1-70. Sherd BP-21 (Cat. no. 167).

Despite the distinctive decoration of the additional Unai Bapot sherd, its temper sand implies that it derives from the same local ceramic industry as the other Unai Bapot sherds, and provides no evidence for exotic wares at Unai Bapot.

Comparative material

Table 1-26. Comparative material.

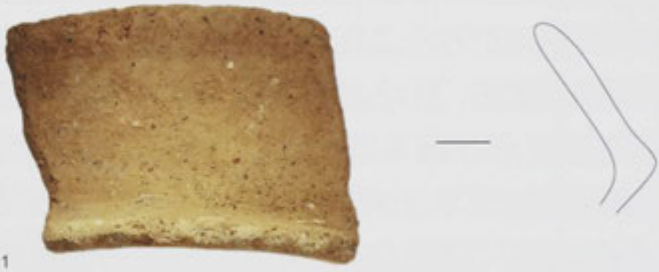
Lab. no.	Site	Pit/Square/Unit	Layer	Find. no.	Depth (cm)	Thermal test
TAN 1	Chaolaiqiao	P1	5			
TAN 2	Chaolaiqiao	P1	5			
TAN 4	Chaolaiqiao	P1	8			
TAN 5	Chaolaiqiao					
TAN 7	Chaolaiqiao		Extension layer III-6			
TAN 8	Chaolaiqiao					
TAN 9	Chaolaiqiao					
TAN 10	Chaolaiqiao					
TAN 11	Chaolaiqiao					
TAN 12	Chaolaiqiao					
TAN 13	Chaolaiqiao					
TAN 14	Chaolaiqiao					
NAG 1	Nagsabaran	P10	14	–		
NAG 2	Nagsabaran	P9	15	–		
NAG 3	Nagsabaran	P10	14	–		
NAG 4	Nagsabaran	P9	11	–		
NAG 5	Nagsabaran	P10	16	–		
NAG 6	Nagsabaran	P9	13B	–		
NAG 7	Nagsabaran	P9	12	–		
NAG 8	Nagsabaran	P9	15	–		
NAG 11	Nagsabaran	P9	13	–		
NAG 12	Nagsabaran	P9	12A	–		
NAG 16	Nagsabaran	P9	16	–		
NAG 17	Nagsabaran	P9	15	–		
NAG 18	Nagsabaran	P9	12	–		
AME 1		Sq W	7	26		
AME 2		Sq W A	4	58		
AME 11			5	22		
AME 15	Site 1	Sq M	7	65		
AME 20	Site 1	Sq W F	8	91		
AME 23	Site 1	Sq W E	9	85		
AME 25	Site 1	Sq W	7	93		
AME 26	Site 1	Sq W A	5A	72		
ULG 1		U1		125	190-200	x
ULG 2		U5 Sq 1			240	
ULG 3						x
ULG 4		U5		207	190-200	x
ULG 5		U1		208	190-200	
ULG 6		U1			240	x
ULG 7		U5		89	210-220	
ULG 8		U1		211	210-220	
ULG 11		U4			150-160	
ULG 12		U1		195	170-180	
ULG 14						x
ULG 14		U5 Sq 1			240	x

Chaolaiqiao, Taiwan (TAN)

TAN 1

Data sheet

Fig 1-71.



1:1

1:4

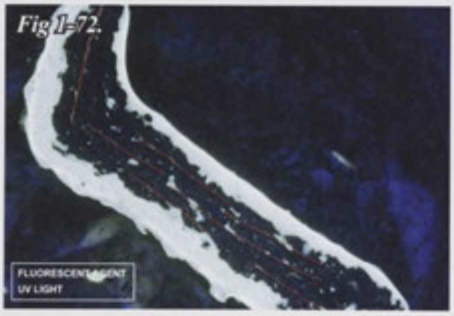


Fig 1-72.

Fig 1-73.

Table 1-27. Temper data.

Number of Objects	Area Fraction	Area (mm²)	Measured Area (mm²)
520	0.265	2.097	7.911

Feature	Mean	SD	Minimum	Maximum
Area (mm²)	0.004	0.03	0.00002	0.378
Equivalent Diameter (mm)	0.026	0.067	0.005	0.694
Circularity	0.57	0.202	0.068	0.96
Max Feret (mm²)	0.04	0.1	0.01	0.989

Class (mm²)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.01-0.02	280	53.85	280	53.85
0.02-0.03	102	19.62	382	73.46
0.03-0.04	48	9.23	430	82.69
0.04-0.05	34	6.54	464	89.23
0.05-0.06	20	3.85	484	93.08
0.06-0.07	5	0.96	489	94.04
0.07-0.08	5	0.96	494	95
0.08-0.09	4	0.77	498	95.77
0.09-0.10	2	0.38	500	96.15
0.10-0.11	3	0.58	503	96.73
0.12-0.13	1	0.19	504	96.92
0.14-0.15	1	0.19	505	97.12

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.18-0.19	1	0.19	506	97.31
0.19-0.20	2	0.38	508	97.69
0.31-0.32	1	0.19	509	97.88
0.36-0.37	1	0.19	510	98.08
0.41-0.42	1	0.19	511	98.27
0.44-0.45	1	0.19	512	98.46
0.50-0.51	1	0.19	513	98.65
0.52-0.53	1	0.19	514	98.85
0.73-0.74	1	0.19	515	99.04
0.75-0.76	1	0.19	516	99.23
0.80-0.81	1	0.19	517	99.42
0.85-0.86	1	0.19	518	99.62
0.93-0.94	1	0.19	519	99.81
0.98-0.99	1	0.19	520	100

TAN 2

Data sheet

Fig 1-74.

1:1

1:4

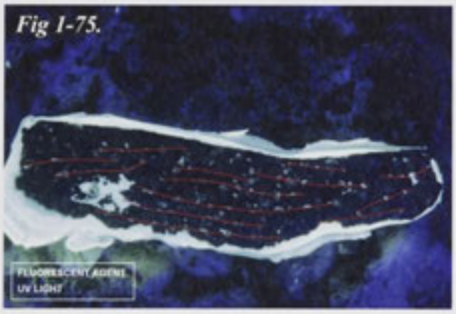


Fig 1-75.

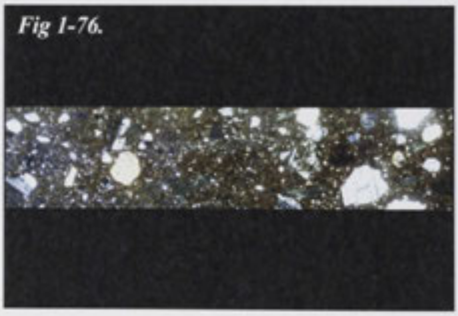


Fig 1-76.

Table 1-28. Temper data

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
873	0.234	1.851	7.894

Feature	Mean	SD	Minimum	Maximum
Area (mm^2)	N/A	N/A	N/A	N/A
Equivalent Diameter (mm)	N/A	N/A	N/A	N/A
Circularity	N/A	N/A	N/A	N/A
Max Feret (mm^2)	N/A	N/A	N/A	N/A

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.01-0.02	491	56.24	491	56.24
0.02-0.03	173	19.82	664	76.06
0.03-0.04	76	8.71	740	84.77
0.04-0.05	46	5.27	786	90.03
0.05-0.06	28	3.21	814	93.24
0.06-0.07	6	0.69	820	93.93
0.07-0.08	3	0.34	823	94.27
0.08-0.09	4	0.46	827	94.73
0.09-0.10	3	0.34	830	95.07
0.10-0.11	6	0.69	836	95.76
0.11-0.12	1	0.11	837	95.88
0.12-0.13	2	0.23	839	96.11
0.13-0.14	3	0.34	842	96.45

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.14-0.15	0	0	842	96.45
0.15-0.16	1	0.11	843	96.56
0.16-0.17	3	0.34	846	96.91
0.17-0.18	1	0.11	847	97.02
0.18-0.19	1	0.11	848	97.14
0.19-0.20	1	0.11	849	97.25
0.20-0.21	1	0.11	850	97.37
0.21-0.22	4	0.46	854	97.82
0.22-0.23	1	0.11	855	97.94
0.23-0.24	2	0.23	857	98.17
0.24-0.25	3	0.34	860	98.51
0.25-0.26	0	0	860	98.51
0.26-0.27	0	0	860	98.51
0.27-0.28	1	0.11	861	98.63
0.28-0.29	0	0	861	98.63
0.29-0.30	2	0.23	863	98.85
0.30-0.31	0	0	863	98.85
0.31-0.32	0	0	863	98.85
0.32-0.33	1	0.11	864	98.97
0.33-0.34	0	0	864	98.97
0.34-0.35	0	0	864	98.97
0.35-0.36	0	0	864	98.97
0.36-0.37	0	0	864	98.97
0.37-0.38	1	0.11	865	99.08
0.38-0.39	0	0	865	99.08
0.39-0.40	0	0	865	99.08
0.40-0.41	0	0	865	99.08
0.41-0.42	0	0	865	99.08
0.42-0.43	0	0	865	99.08
0.43-0.44	1	0.11	866	99.2
0.44-0.45	1	0.11	867	99.31
0.45-0.46	0	0	867	99.31
0.46-0.47	0	0	867	99.31
0.47-0.48	0	0	867	99.31
0.48-0.49	1	0.11	868	99.43
0.49-0.50	0	0	868	99.43
0.50-0.51	0	0	868	99.43
0.51-0.52	0	0	868	99.43
0.52-0.53	0	0	868	99.43
0.53-0.54	1	0.11	869	99.54
0.54-0.55	1	0.11	870	99.66
0.55-0.56	0	0	870	99.66
0.56-0.57	0	0	870	99.66
0.57-0.58	1	0.11	871	99.77
0.58-0.59	0	0	871	99.77
0.59-0.60	1	0.11	872	99.89
0.60-0.61	0	0	872	99.89
0.61-0.62	0	0	872	99.89

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.62-0.63	0	0	872	99.89
0.63-0.64	0	0	872	99.89
0.64-0.65	0	0	872	99.89
0.65-0.66	1	0.11	873	100

TAN 5

Data sheet

Fig 1-77.

1:1

1:4

ø17 cm

Fig 1-78.

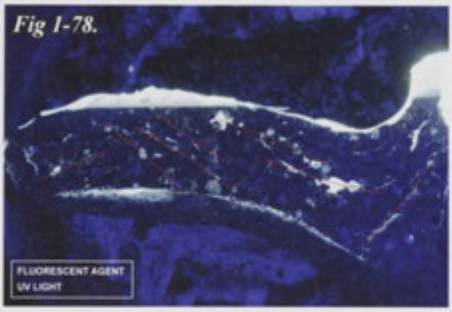


Fig 1-79.

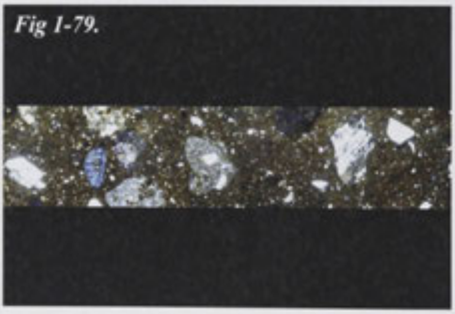


Table 1-29. Temper data

Number of Objects	Area Fraction	Area (mm²)	Measured Area (mm²)
686	0.26	2.054	7.892

Feature	Mean	SD	Minimum	Maximum
Area (mm²)	N/A	N/A	N/A	N/A
Equivalent Diameter (mm)	N/A	N/A	N/A	N/A
Circularity	N/A	N/A	N/A	N/A
Max Feret (mm²)	N/A	N/A	N/A	N/A

Class (mm²)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.01-0.02	380	55.39	380	55.39
0.02-0.03	132	19.24	512	74.64
0.03-0.04	73	10.64	585	85.28
0.04-0.05	27	3.94	612	89.21
0.05-0.06	29	4.23	641	93.44
0.06-0.07	8	1.17	649	94.61
0.07-0.08	8	1.17	657	95.77
0.08-0.09	4	0.58	661	96.36
0.09-0.10	1	0.15	662	96.5
0.10-0.11	5	0.73	667	97.23
0.11-0.12	0	0	667	97.23
0.12-0.13	1	0.15	668	97.38
0.13-0.14	0	0	668	97.38

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Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.14-0.15	0	0	668	97.38
0.15-0.16	0	0	668	97.38
0.16-0.17	1	0.15	669	97.52
0.17-0.18	3	0.44	672	97.96
0.18-0.19	0	0	672	97.96
0.19-0.20	0	0	672	97.96
0.20-0.21	3	0.44	675	98.4
0.21-0.22	0	0	675	98.4
0.22-0.23	1	0.15	676	98.54
0.23-0.24	0	0	676	98.54
0.24-0.25	0	0	676	98.54
0.25-0.26	0	0	676	98.54
0.26-0.27	0	0	676	98.54
0.27-0.28	0	0	676	98.54
0.28-0.29	0	0	676	98.54
0.29-0.30	0	0	676	98.54
0.30-0.31	1	0.15	677	98.69
0.31-0.32	0	0	677	98.69
0.32-0.33	0	0	677	98.69
0.33-0.34	0	0	677	98.69
0.34-0.35	0	0	677	98.69
0.35-0.36	0	0	677	98.69
0.36-0.37	0	0	677	98.69
0.37-0.38	0	0	677	98.69
0.38-0.39	0	0	677	98.69
0.39-0.40	2	0.29	679	98.98
0.40-0.41	0	0	679	98.98
0.41-0.42	0	0	679	98.98
0.42-0.43	0	0	679	98.98
0.43-0.44	0	0	679	98.98
0.44-0.45	0	0	679	98.98
0.45-0.46	0	0	679	98.98
0.46-0.47	0	0	679	98.98
0.47-0.48	0	0	679	98.98
0.48-0.49	1	0.15	680	99.13
0.49-0.50	0	0	680	99.13
0.50-0.51	0	0	680	99.13
0.51-0.52	0	0	680	99.13
0.52-0.53	0	0	680	99.13
0.53-0.54	1	0.15	681	99.27
0.54-0.55	0	0	681	99.27
0.55-0.56	0	0	681	99.27
0.56-0.57	0	0	681	99.27
0.57-0.58	0	0	681	99.27
0.58-0.59	0	0	681	99.27
0.59-0.60	1	0.15	682	99.42
0.60-0.61	0	0	682	99.42
0.61-0.62	0	0	682	99.42

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.62-0.63	1	0.15	683	99.56
0.63-0.64	0	0	683	99.56
0.64-0.65	0	0	683	99.56
0.65-0.66	0	0	683	99.56
0.66-0.67	0	0	683	99.56
0.67-0.68	0	0	683	99.56
0.68-0.69	0	0	683	99.56
0.69-0.70	0	0	683	99.56
0.70-0.71	0	0	683	99.56
0.71-0.72	0	0	683	99.56
0.72-0.73	0	0	683	99.56
0.73-0.74	0	0	683	99.56
0.74-0.75	0	0	683	99.56
0.75-0.76	0	0	683	99.56
0.76-0.77	0	0	683	99.56
0.77-0.78	0	0	683	99.56
0.78-0.79	0	0	683	99.56
0.79-0.80	0	0	683	99.56
0.80-0.81	1	0.15	684	99.71
0.81-0.82	0	0	684	99.71
0.82-0.83	1	0.15	685	99.85
0.83-0.84	0	0	685	99.85
0.84-0.85	0	0	685	99.85
0.85-0.86	0	0	685	99.85
0.86-0.87	0	0	685	99.85
0.87-0.88	0	0	685	99.85
0.88-0.89	0	0	685	99.85
0.89-0.90	0	0	685	99.85
0.90-0.91	0	0	685	99.85
0.91-0.92	0	0	685	99.85
0.92-0.93	0	0	685	99.85
0.93-0.94	1	0.15	686	100

TAN 7

Data sheet

Fig 1-80.

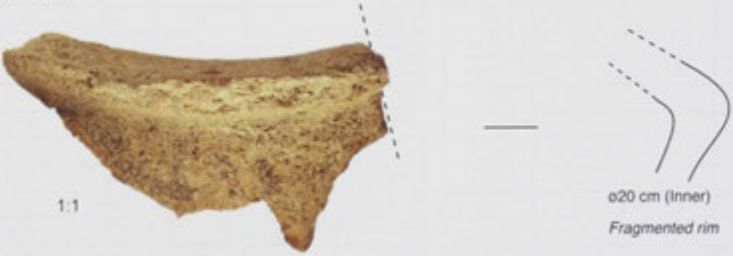


Fig 1-81.

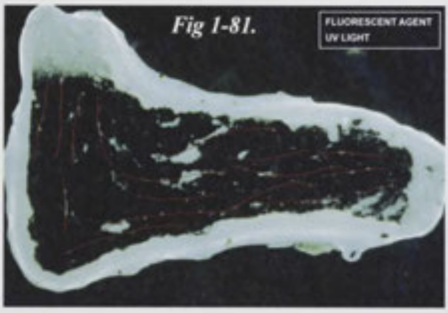


Fig 1-82.

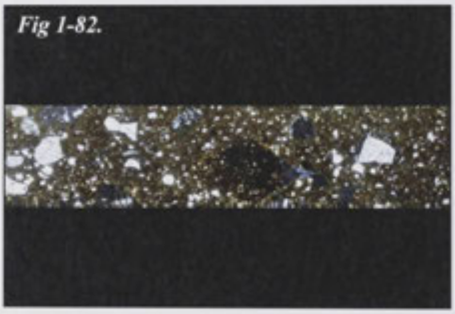


Table 1-30. Temper data.

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
1177	0.198	1.569	7.903

Feature	Mean	SD	Minimum	Maximum
Area (mm^2)	N/A	N/A	N/A	N/A
Equivalent Diameter (mm)	N/A	N/A	N/A	N/A
Circularity	N/A	N/A	N/A	N/A
Max Feret (mm^2)	N/A	N/A	N/A	N/A

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.01-0.02	627	53.27	627	53.27
0.02-0.03	215	18.27	842	71.54
0.03-0.04	116	9.86	958	81.39
0.04-0.05	72	6.12	1030	87.51
0.05-0.06	42	3.57	1072	91.08
0.06-0.07	31	2.63	1103	93.71
0.07-0.08	17	1.44	1120	95.16
0.08-0.09	15	1.27	1135	96.43
0.09-0.10	6	0.51	1141	96.94
0.10-0.11	7	0.59	1148	97.54
0.11-0.12	2	0.17	1150	97.71
0.12-0.13	5	0.42	1155	98.13
0.13-0.14	5	0.42	1160	98.56
0.14-0.15	0	0	1160	98.56
0.15-0.16	0	0	1160	98.56
0.16-0.17	0	0	1160	98.56
0.17-0.18	3	0.25	1163	98.81

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.18-0.19	0	0	1163	98.81
0.19-0.20	0	0	1163	98.81
0.20-0.21	1	0.08	1164	98.9
0.21-0.22	0	0	1164	98.9
0.22-0.23	1	0.08	1165	98.98
0.23-0.24	1	0.08	1166	99.07
0.24-0.25	0	0	1166	99.07
0.25-0.26	1	0.08	1167	99.15
0.26-0.27	0	0	1167	99.15
0.27-0.28	0	0	1167	99.15
0.28-0.29	1	0.08	1168	99.24
0.29-0.30	0	0	1168	99.24
0.30-0.31	0	0	1168	99.24
0.31-0.32	0	0	1168	99.24
0.32-0.33	1	0.08	1169	99.32
0.33-0.34	0	0	1169	99.32
0.34-0.35	0	0	1169	99.32
0.35-0.36	0	0	1169	99.32
0.36-0.37	1	0.08	1170	99.41
0.37-0.38	1	0.08	1171	99.49
0.38-0.39	0	0	1171	99.49
0.39-0.40	0	0	1171	99.49
0.40-0.41	0	0	1171	99.49
0.41-0.42	0	0	1171	99.49
0.42-0.43	0	0	1171	99.49
0.43-0.44	0	0	1171	99.49
0.44-0.45	1	0.08	1172	99.58
0.45-0.46	0	0	1172	99.58
0.46-0.47	1	0.08	1173	99.66
0.47-0.48	0	0	1173	99.66
0.48-0.49	0	0	1173	99.66
0.49-0.50	1	0.08	1174	99.75
0.50-0.51	0	0	1174	99.75
0.51-0.52	0	0	1174	99.75
0.52-0.53	0	0	1174	99.75
0.53-0.54	1	0.08	1175	99.83
0.54-0.55	0	0	1175	99.83
0.55-0.56	0	0	1175	99.83
0.56-0.57	0	0	1175	99.83
0.57-0.58	0	0	1175	99.83
0.58-0.59	0	0	1175	99.83
0.59-0.60	0	0	1175	99.83
0.60-0.61	0	0	1175	99.83
0.61-0.62	0	0	1175	99.83
0.62-0.63	0	0	1175	99.83
0.63-0.64	0	0	1175	99.83
0.64-0.65	0	0	1175	99.83
0.65-0.66	0	0	1175	99.83
0.66-0.67	1	0.08	1176	99.92
0.67-0.68	0	0	1176	99.92
0.68-0.69	0	0	1176	99.92
0.69-0.70	0	0	1176	99.92
0.70-0.71	0	0	1176	99.92
0.71-0.72	0	0	1176	99.92
0.72-0.73	0	0	1176	99.92
0.73-0.74	0	0	1176	99.92
0.74-0.75	0	0	1176	99.92
0.75-0.76	0	0	1176	99.92
0.76-0.77	0	0	1176	99.92
0.77-0.78	0	0	1176	99.92
0.78-0.79	1	0.08	1177	100

TAN 11

Data sheet

Fig 1-83.

1:1

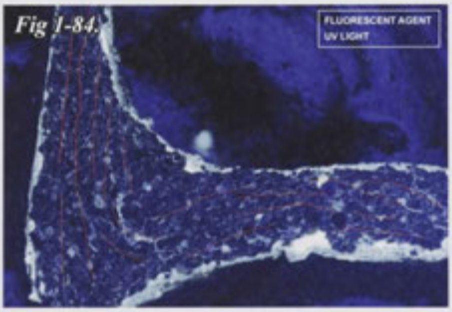


Fig 1-84.

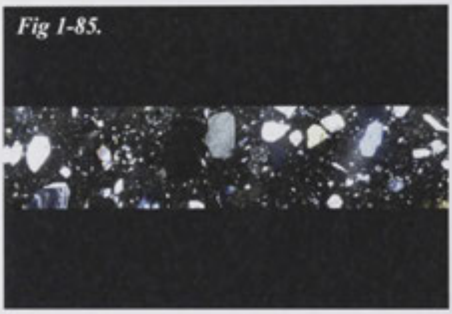


Fig 1-85.

Table 1-31. Temper data.

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
551	0.226	1.789	7.903

Feature	Mean	SD	Minimum	Maximum
Area (mm^2)	N/A	N/A	N/A	N/A
Equivalent Diameter (mm)	N/A	N/A	N/A	N/A
Circularity	N/A	N/A	N/A	N/A
Max Feret (mm^2)	N/A	N/A	N/A	N/A

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.01-0.02	255	46.28	255	46.28
0.02-0.03	106	19.24	361	65.52
0.03-0.04	56	10.16	417	75.68
0.04-0.05	32	5.81	449	81.49
0.05-0.06	29	5.26	478	86.75
0.06-0.07	13	2.36	491	89.11
0.07-0.08	7	1.27	498	90.38
0.08-0.09	9	1.63	507	92.01
0.09-0.10	4	0.73	511	92.74
0.10-0.11	2	0.36	513	93.1
0.11-0.12	2	0.36	515	93.47
0.12-0.13	1	0.18	516	93.65
0.13-0.14	2	0.36	518	94.01
0.14-0.15	1	0.18	519	94.19
0.15-0.16	2	0.36	521	94.56
0.16-0.17	1	0.18	522	94.74
0.17-0.18	1	0.18	523	94.92

Class (mm²)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.18-0.19	1	0.18	524	95.1
0.19-0.20	0	0	524	95.1
0.20-0.21	2	0.36	526	95.46
0.21-0.22	2	0.36	528	95.83
0.22-0.23	1	0.18	529	96.01
0.23-0.24	2	0.36	531	96.37
0.24-0.25	1	0.18	532	96.55
0.25-0.26	2	0.36	534	96.91
0.26-0.27	0	0	534	96.91
0.27-0.28	0	0	534	96.91
0.28-0.29	0	0	534	96.91
0.29-0.30	1	0.18	535	97.1
0.30-0.31	1	0.18	536	97.28
0.31-0.32	0	0	536	97.28
0.32-0.33	2	0.36	538	97.64
0.33-0.34	2	0.36	540	98
0.34-0.35	1	0.18	541	98.19
0.35-0.36	0	0	541	98.19
0.36-0.37	1	0.18	542	98.37
0.37-0.38	0	0	542	98.37
0.38-0.39	1	0.18	543	98.55
0.39-0.40	0	0	543	98.55
0.40-0.41	2	0.36	545	98.91
0.41-0.42	0	0	545	98.91
0.42-0.43	0	0	545	98.91
0.43-0.44	2	0.36	547	99.27
0.44-0.45	0	0	547	99.27
0.45-0.46	0	0	547	99.27
0.46-0.47	0	0	547	99.27
0.47-0.48	0	0	547	99.27
0.48-0.49	0	0	547	99.27
0.49-0.50	0	0	547	99.27
0.50-0.51	1	0.18	548	99.46
0.51-0.52	1	0.18	549	99.64
0.52-0.53	0	0	549	99.64
0.53-0.54	0	0	549	99.64
0.54-0.55	0	0	549	99.64
0.55-0.56	0	0	549	99.64
0.56-0.57	0	0	549	99.64
0.57-0.58	0	0	549	99.64
0.58-0.59	0	0	549	99.64
0.59-0.60	0	0	549	99.64
0.60-0.61	0	0	549	99.64
0.61-0.62	0	0	549	99.64
0.62-0.63	1	0.18	550	99.82
0.63-0.64	0	0	550	99.82
0.64-0.65	0	0	550	99.82
0.65-0.66	0	0	550	99.82

Class (mm²)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.66-0.67	0	0	550	99.82
0.67-0.68	1	0.18	551	100

TAN 12

Data sheet

Fig 1-86.

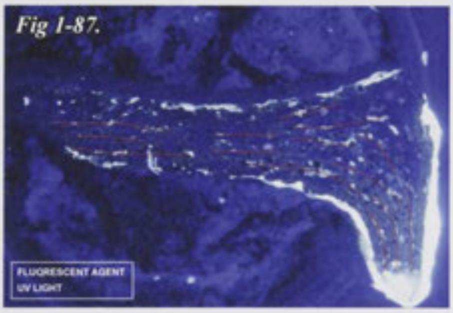


Fig 1-87.

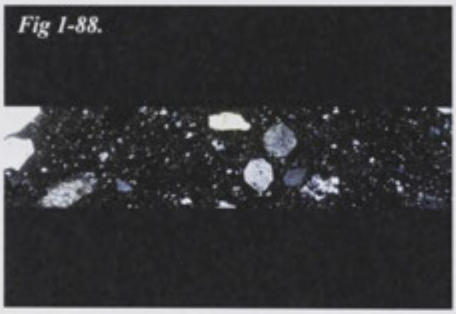


Fig 1-88.

Table 1-32. Temper data

Number of Objects	Area Fraction	Area (mm²)	Measured Area (mm²)
985	0.187	1.819	9.747

Feature	Mean	SD	Minimum	Maximum
Area (mm²)	N/A	N/A	N/A	N/A
Equivalent Diameter (mm)	N/A	N/A	N/A	N/A
Circularity	N/A	N/A	N/A	N/A
Max Feret (mm²)	N/A	N/A	N/A	N/A

Class (mm²)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.01-0.02	567	57.56	567	57.56
0.02-0.03	210	21.32	777	78.88
0.03-0.04	88	8.93	865	87.82
0.04-0.05	44	4.47	909	92.28
0.05-0.06	20	2.03	929	94.31
0.06-0.07	9	0.91	938	95.23
0.07-0.08	12	1.22	950	96.45
0.08-0.09	5	0.51	955	96.95
0.09-0.10	5	0.51	960	97.46
0.10-0.11	1	0.1	961	97.56
0.11-0.12	0	0	961	97.56
0.12-0.13	1	0.1	962	97.66
0.13-0.14	3	0.3	965	97.97

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.14-0.15	0	0	965	97.97
0.15-0.16	1	0.1	966	98.07
0.16-0.17	2	0.2	968	98.27
0.22-0.23	1	0.1	969	98.38
0.24-0.25	1	0.1	970	98.48
0.25-0.26	1	0.1	971	98.58
0.26-0.27	2	0.2	973	98.78
0.31-0.32	1	0.1	974	98.88
0.36-0.37	1	0.1	975	98.98
0.42-0.43	1	0.1	976	99.09
0.43-0.44	1	0.1	977	99.19
0.44-0.45	2	0.2	979	99.39
0.45-0.46	1	0.1	980	99.49
0.56-0.57	2	0.2	982	99.7
0.57-0.58	1	0.1	983	99.8
0.90-0.91	1	0.1	984	99.9
1.10-1.11	1	0.1	985	100

TAN 13

Data sheet

Fig 1-89.

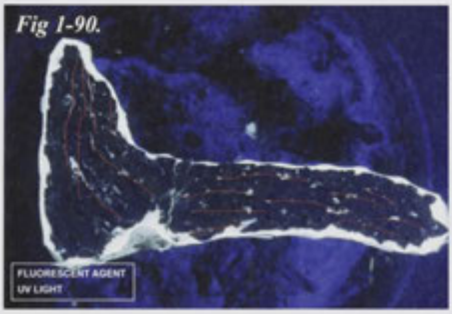


Fig 1-90.

Fig 1-91.

Table 1-34. Temper data.

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
597	0.219	1.727	7.893

Feature	Mean	SD	Minimum	Maximum
Area (mm^2)	N/A	N/A	N/A	N/A
Equivalent Diameter (mm)	N/A	N/A	N/A	N/A
Circularity	N/A	N/A	N/A	N/A
Max Feret (mm^2)	N/A	N/A	N/A	N/A

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.01-0.02	339	56.78	339	56.78
0.02-0.03	124	20.77	463	77.55
0.03-0.04	52	8.71	515	86.26
0.04-0.05	25	4.19	540	90.45
0.05-0.06	13	2.18	553	92.63
0.06-0.07	4	0.67	557	93.3
0.07-0.08	8	1.34	565	94.64
0.08-0.09	5	0.84	570	95.48
0.09-0.10	3	0.5	573	95.98
0.10-0.11	4	0.67	577	96.65
0.11-0.12	2	0.34	579	96.98
0.12-0.13	0	0	579	96.98
0.13-0.14	2	0.34	581	97.32
0.14-0.15	1	0.17	582	97.49
0.15-0.16	1	0.17	583	97.65
0.18-0.19	1	0.17	584	97.82
0.22-0.23	1	0.17	585	97.99
0.29-0.30	1	0.17	586	98.16
0.32-0.33	1	0.17	587	98.32
0.35-0.36	1	0.17	588	98.49
0.43-0.44	1	0.17	589	98.66
0.49-0.50	1	0.17	590	98.83

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.54-0.55	1	0.17	591	98.99
0.56-0.57	2	0.34	593	99.33
0.62-0.63	1	0.17	594	99.5
0.63-0.64	1	0.17	595	99.66
0.78-0.79	1	0.17	596	99.83
0.85-0.86	1	0.17	597	100

TAN 14

Data sheet

Fig 1-92.

Fig 1-93.

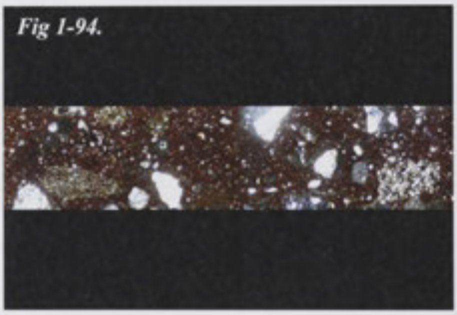


Fig 1-94.

Table 1-35. Temper data.

Number of Objects	Area Fraction	Area (mm²)	Measured Area (mm²)
633	0.26	2.058	7.906

Feature	Mean	SD	Minimum	Maximum
Area (mm²)	N/A	N/A	N/A	N/A
Equivalent Diameter (mm)	N/A	N/A	N/A	N/A
Circularity	N/A	N/A	N/A	N/A
Max Feret (mm²)	N/A	N/A	N/A	N/A

Class (mm²)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.01-0.02	344	54.34	344	54.34
0.02-0.03	128	20.22	472	74.57
0.03-0.04	46	7.27	518	81.83
0.04-0.05	31	4.9	549	86.73
0.05-0.06	15	2.37	564	89.1
0.06-0.07	21	3.32	585	92.42
0.07-0.08	7	1.11	592	93.52
0.08-0.09	6	0.95	598	94.47
0.09-0.10	3	0.47	601	94.94
0.10-0.11	4	0.63	605	95.58
0.11-0.12	3	0.47	608	96.05
0.12-0.13	3	0.47	611	96.52
0.13-0.14	2	0.32	613	96.84
0.14-0.15	1	0.16	614	97
0.15-0.16	0	0	614	97
0.16-0.17	0	0	614	97
0.17-0.18	1	0.16	615	97.16

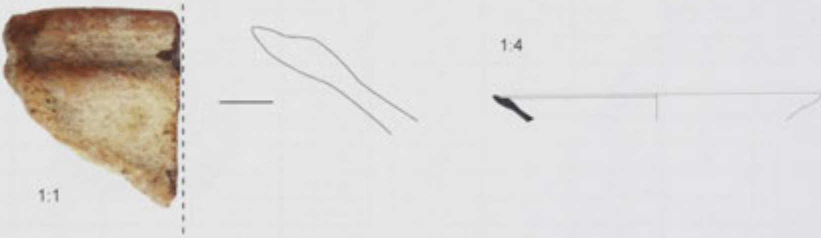
0.18-0.19	0	0	615	97.16
0.19-0.20	1	0.16	616	97.31
0.20-0.21	0	0	616	97.31
0.21-0.22	0	0	616	97.31
0.22-0.23	0	0	616	97.31
0.23-0.24	1	0.16	617	97.47
0.24-0.25	0	0	617	97.47
0.25-0.26	0	0	617	97.47
0.26-0.27	1	0.16	618	97.63
0.27-0.28	0	0	618	97.63
0.28-0.29	1	0.16	619	97.79
0.29-0.30	2	0.32	621	98.1
0.30-0.31	1	0.16	622	98.26
0.31-0.32	0	0	622	98.26
0.32-0.33	1	0.16	623	98.42
0.33-0.34	0	0	623	98.42
0.34-0.35	0	0	623	98.42
0.35-0.36	0	0	623	98.42
0.36-0.37	0	0	623	98.42
0.37-0.38	0	0	623	98.42
0.38-0.39	1	0.16	624	98.58
0.39-0.40	0	0	624	98.58
0.40-0.41	0	0	624	98.58
0.41-0.42	0	0	624	98.58
0.42-0.43	0	0	624	98.58
0.43-0.44	1	0.16	625	98.74
0.44-0.45	1	0.16	626	98.89
0.45-0.46	0	0	626	98.89
0.46-0.47	0	0	626	98.89
0.47-0.48	0	0	626	98.89
0.48-0.49	0	0	626	98.89
0.49-0.50	0	0	626	98.89
0.50-0.51	0	0	626	98.89
0.51-0.52	0	0	626	98.89
0.52-0.53	2	0.32	628	99.21
0.53-0.54	0	0	628	99.21
0.54-0.55	0	0	628	99.21
0.55-0.56	0	0	628	99.21
0.56-0.57	0	0	628	99.21
0.57-0.58	0	0	628	99.21
0.58-0.59	1	0.16	629	99.37
0.59-0.60	0	0	629	99.37
0.60-0.61	0	0	629	99.37
0.61-0.62	0	0	629	99.37
0.62-0.63	1	0.16	630	99.53
0.63-0.64	0	0	630	99.53
0.64-0.65	0	0	630	99.53
0.65-0.66	0	0	630	99.53
0.66-0.67	0	0	630	99.53
0.67-0.68	0	0	630	99.53

0.68-0.69	0	0	630	99.53
0.69-0.70	0	0	630	99.53
0.70-0.71	0	0	630	99.53
0.71-0.72	0	0	630	99.53
0.72-0.73	1	0.16	631	99.68
0.73-0.74	0	0	631	99.68
0.74-0.75	0	0	631	99.68
0.75-0.76	0	0	631	99.68
0.76-0.77	0	0	631	99.68
0.77-0.78	0	0	631	99.68
0.78-0.79	0	0	631	99.68
0.79-0.80	0	0	631	99.68
0.80-0.81	0	0	631	99.68
0.81-0.82	0	0	631	99.68
0.82-0.83	0	0	631	99.68
0.83-0.84	0	0	631	99.68
0.84-0.85	0	0	631	99.68
0.85-0.86	0	0	631	99.68
0.86-0.87	0	0	631	99.68
0.87-0.88	0	0	631	99.68
0.88-0.89	0	0	631	99.68
0.89-0.90	0	0	631	99.68
0.90-0.91	0	0	631	99.68
0.91-0.92	0	0	631	99.68
0.92-0.93	0	0	631	99.68
0.93-0.94	0	0	631	99.68
0.94-0.95	1	0.16	632	99.84
0.95-0.96	0	0	632	99.84
0.96-0.97	0	0	632	99.84
0.97-0.98	0	0	632	99.84
0.98-0.99	0	0	632	99.84
0.99-1.00	0	0	632	99.84
1.00-1.01	0	0	632	99.84
1.01-1.02	0	0	632	99.84
1.02-1.03	0	0	632	99.84
1.03-1.04	0	0	632	99.84
1.04-1.05	0	0	632	99.84
1.05-1.06	0	0	632	99.84
1.06-1.07	0	0	632	99.84
1.07-1.08	0	0	632	99.84
1.08-1.09	0	0	632	99.84
1.09-1.10	0	0	632	99.84
1.10-1.11	0	0	632	99.84
1.11-1.12	1	0.16	633	100

TAN 15

Data sheet

Fig 1-95.



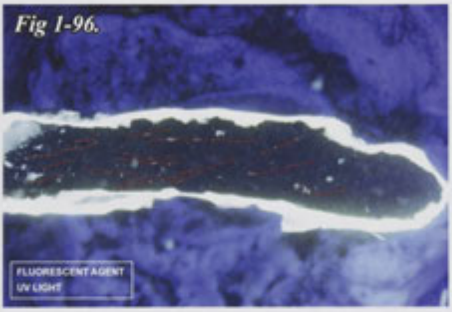


Fig 1-96.


Fig 1-97.

Table 1-36. Temper data.

Number of Objects	Area Fraction	Area (mm²)	Measured Area (mm²)
318	0.2	1.587	7.917

Feature	Mean	SD	Minimum	Maximum
Area (mm²)	N/A	N/A	N/A	N/A
Equivalent Diameter (mm)	N/A	N/A	N/A	N/A
Circularity	N/A	N/A	N/A	N/A
Max Feret (mm²)	N/A	N/A	N/A	N/A

Class (mm²)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.01-0.02	145	45.6	145	45.6
0.02-0.03	70	22.01	215	67.61
0.03-0.04	23	7.23	238	74.84
0.04-0.05	22	6.92	260	81.76
0.05-0.06	11	3.46	271	85.22
0.06-0.07	10	3.14	281	88.36
0.07-0.08	4	1.26	285	89.62
0.08-0.09	3	0.94	288	90.57
0.09-0.10	5	1.57	293	92.14
0.10-0.11	3	0.94	296	93.08
0.11-0.12	1	0.31	297	93.4
0.12-0.13	0	0	297	93.4
0.13-0.14	1	0.31	298	93.71
0.14-0.15	3	0.94	301	94.65
0.15-0.16	2	0.63	303	95.28
0.16-0.17	2	0.63	305	95.91
0.17-0.18	1	0.31	306	96.23
0.18-0.19	1	0.31	307	96.54
0.19-0.20	0	0	307	96.54
0.20-0.21	0	0	307	96.54
0.21-0.22	1	0.31	308	96.86

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.22-0.23	0	0	308	96.86
0.23-0.24	1	0.31	309	97.17
0.24-0.25	0	0	309	97.17
0.25-0.26	1	0.31	310	97.48
0.26-0.27	0	0	310	97.48
0.27-0.28	0	0	310	97.48
0.28-0.29	0	0	310	97.48
0.29-0.30	0	0	310	97.48
0.30-0.31	0	0	310	97.48
0.31-0.32	0	0	310	97.48
0.32-0.33	1	0.31	311	97.8
0.33-0.34	0	0	311	97.8
0.34-0.35	0	0	311	97.8
0.35-0.36	0	0	311	97.8
0.36-0.37	0	0	311	97.8
0.37-0.38	0	0	311	97.8
0.38-0.39	0	0	311	97.8
0.39-0.40	0	0	311	97.8
0.40-0.41	0	0	311	97.8
0.41-0.42	0	0	311	97.8
0.42-0.43	0	0	311	97.8
0.43-0.44	0	0	311	97.8
0.44-0.45	0	0	311	97.8
0.45-0.46	0	0	311	97.8
0.46-0.47	0	0	311	97.8
0.47-0.48	0	0	311	97.8
0.48-0.49	1	0.31	312	98.11
0.49-0.50	0	0	312	98.11
0.50-0.51	1	0.31	313	98.43
0.51-0.52	0	0	313	98.43
0.52-0.53	0	0	313	98.43
0.53-0.54	1	0.31	314	98.74
0.54-0.55	1	0.31	315	99.06
0.55-0.56	0	0	315	99.06
0.56-0.57	0	0	315	99.06
0.57-0.58	0	0	315	99.06
0.58-0.59	0	0	315	99.06
0.59-0.60	1	0.31	316	99.37
0.60-0.61	0	0	316	99.37
0.61-0.62	0	0	316	99.37
0.62-0.63	0	0	316	99.37
0.63-0.64	0	0	316	99.37
0.64-0.65	0	0	316	99.37
0.65-0.66	0	0	316	99.37
0.66-0.67	0	0	316	99.37
0.67-0.68	0	0	316	99.37

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.68-0.69	1	0.31	317	99.69
0.69-0.70	0	0	317	99.69
0.70-0.71	0	0	317	99.69
0.71-0.72	0	0	317	99.69
0.72-0.73	0	0	317	99.69
0.73-0.74	0	0	317	99.69
0.74-0.75	0	0	317	99.69
0.75-0.76	0	0	317	99.69
0.76-0.77	0	0	317	99.69
0.77-0.78	0	0	317	99.69
0.78-0.79	0	0	317	99.69
0.79-0.80	0	0	317	99.69
...				
1.00-1.01	0	0	317	99.69
1.01-1.02	0	0	317	99.69
1.02-1.03	0	0	317	99.69
1.03-1.04	0	0	317	99.69
1.04-1.05	0	0	317	99.69
1.05-1.06	0	0	317	99.69
1.06-1.07	0	0	317	99.69
1.07-1.08	0	0	317	99.69
1.08-1.09	0	0	317	99.69
1.09-1.10	0	0	317	99.69
1.10-1.11	0	0	317	99.69
1.11-1.12	0	0	317	99.69
1.12-1.13	0	0	317	99.69
1.13-1.14	0	0	317	99.69
1.14-1.15	0	0	317	99.69
1.15-1.16	0	0	317	99.69
1.16-1.17	0	0	317	99.69
1.17-1.18	0	0	317	99.69
1.18-1.19	0	0	317	99.69
1.19-1.20	0	0	317	99.69
1.20-1.21	0	0	317	99.69
1.21-1.22	0	0	317	99.69
1.22-1.23	0	0	317	99.69
1.23-1.24	1	0.31	318	100

TAN 16

Data sheet

Fig 1-98.

1:1

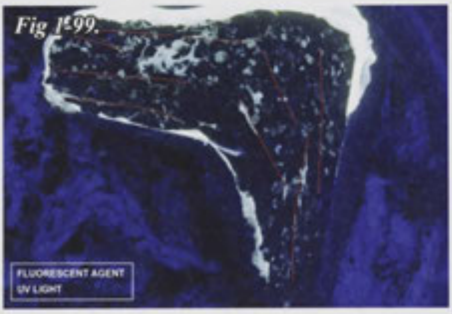


Fig 1-99.

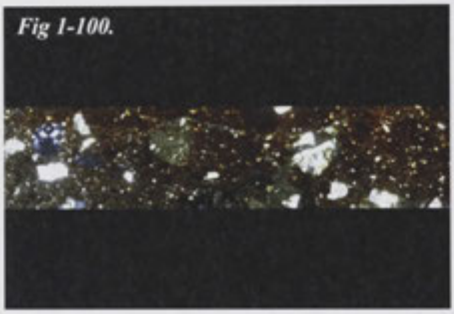


Fig 1-100.

Table 1-37. Temper data.

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
498	0.126	0.994	7.896

Feature	Mean	SD	Minimum	Maximum
Area (mm^2)	N/A	N/A	N/A	N/A
Equivalent Diameter (mm)	N/A	N/A	N/A	N/A
Circularity	N/A	N/A	N/A	N/A
Max Feret (mm^2)	N/A	N/A	N/A	N/A

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.01-0.02	262	52.61	262	52.61
0.02-0.03	108	21.69	370	74.3
0.03-0.04	43	8.63	413	82.93
0.04-0.05	36	7.23	449	90.16
0.05-0.06	12	2.41	461	92.57
0.06-0.07	8	1.61	469	94.18
0.07-0.08	5	1	474	95.18
0.08-0.09	3	0.6	477	95.78
0.09-0.10	0	0	477	95.78
0.10-0.11	2	0.4	479	96.18
0.11-0.12	1	0.2	480	96.39
0.12-0.13	1	0.2	481	96.59
0.13-0.14	0	0	481	96.59
0.14-0.15	1	0.2	482	96.79
0.15-0.16	1	0.2	483	96.99

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.16-0.17	1	0.2	484	97.19
0.17-0.18	1	0.2	485	97.39
0.18-0.19	0	0	485	97.39
0.19-0.20	0	0	485	97.39
0.20-0.21	1	0.2	486	97.59
0.21-0.22	0	0	486	97.59
0.22-0.23	1	0.2	487	97.79
0.23-0.24	0	0	487	97.79
0.24-0.25	1	0.2	488	97.99
0.25-0.26	1	0.2	489	98.19
0.26-0.27	0	0	489	98.19
0.27-0.28	0	0	489	98.19
0.28-0.29	0	0	489	98.19
0.29-0.30	1	0.2	490	98.39
0.30-0.31	1	0.2	491	98.59
0.31-0.32	0	0	491	98.59
0.32-0.33	1	0.2	492	98.8
0.33-0.34	0	0	492	98.8
0.34-0.35	1	0.2	493	99
0.35-0.36	0	0	493	99
0.36-0.37	1	0.2	494	99.2
0.37-0.38	0	0	494	99.2
0.38-0.39	0	0	494	99.2
0.39-0.40	0	0	494	99.2
0.40-0.41	1	0.2	495	99.4
0.41-0.42	0	0	495	99.4
0.42-0.43	0	0	495	99.4
0.43-0.44	0	0	495	99.4
0.44-0.45	1	0.2	496	99.6
0.45-0.46	0	0	496	99.6
0.46-0.47	0	0	496	99.6
0.47-0.48	0	0	496	99.6
0.48-0.49	0	0	496	99.6
0.49-0.50	0	0	496	99.6
0.50-0.51	0	0	496	99.6
0.51-0.52	0	0	496	99.6
0.52-0.53	0	0	496	99.6
0.53-0.54	0	0	496	99.6
0.54-0.55	0	0	496	99.6
0.55-0.56	0	0	496	99.6
0.56-0.57	0	0	496	99.6
0.57-0.58	0	0	496	99.6
0.58-0.59	0	0	496	99.6
0.59-0.60	0	0	496	99.6
0.60-0.61	0	0	496	99.6
0.61-0.62	0	0	496	99.6
0.62-0.63	1	0.2	497	99.8
0.63-0.64	0	0	497	99.8

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.64-0.65	0	0	497	99.8
0.65-0.66	1	0.2	498	100

TAN 17

Data sheet

Fig 1-101.

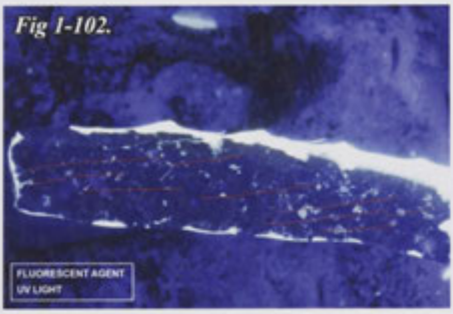


Fig 1-102.

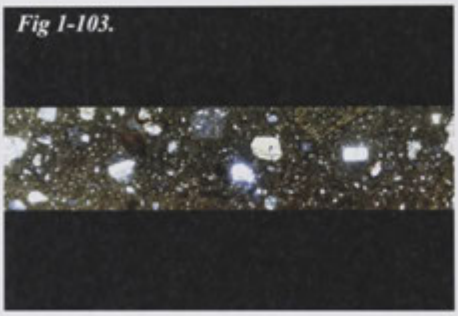


Fig 1-103.

Table 1-38. Temper data.

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
924	0.186	1.466	7.898

Feature	Mean	SD	Minimum	Maximum
Area (mm^2)	N/A	N/A	N/A	N/A
Equivalent Diameter (mm)	N/A	N/A	N/A	N/A
Circularity	N/A	N/A	N/A	N/A
Max Feret (mm^2)	N/A	N/A	N/A	N/A

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.01-0.02	515	55.74	515	55.74
0.02-0.03	182	19.7	697	75.43
0.03-0.04	95	10.28	792	85.71
0.04-0.05	40	4.33	832	90.04
0.05-0.06	30	3.25	862	93.29
0.06-0.07	14	1.52	876	94.81
0.07-0.08	4	0.43	880	95.24
0.08-0.09	7	0.76	887	96
0.09-0.10	1	0.11	888	96.1
0.10-0.11	3	0.32	891	96.43
0.11-0.12	2	0.22	893	96.65
0.12-0.13	1	0.11	894	96.75
0.13-0.14	3	0.32	897	97.08
0.14-0.15	2	0.22	899	97.29
0.15-0.16	0	0	899	97.29
0.16-0.17	4	0.43	903	97.73
0.17-0.18	3	0.32	906	98.05

Class (mm²)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.18-0.19	0	0	906	98.05
0.19-0.20	0	0	906	98.05
0.20-0.21	1	0.11	907	98.16
0.21-0.22	1	0.11	908	98.27
0.22-0.23	1	0.11	909	98.38
0.23-0.24	0	0	909	98.38
0.24-0.25	0	0	909	98.38
0.25-0.26	1	0.11	910	98.48
0.26-0.27	3	0.32	913	98.81
0.27-0.28	1	0.11	914	98.92
0.28-0.29	1	0.11	915	99.03
0.29-0.30	0	0	915	99.03
0.30-0.31	0	0	915	99.03
0.31-0.32	0	0	915	99.03
0.32-0.33	0	0	915	99.03
0.33-0.34	2	0.22	917	99.24
0.34-0.35	0	0	917	99.24
0.35-0.36	0	0	917	99.24
0.36-0.37	0	0	917	99.24
0.37-0.38	1	0.11	918	99.35
0.38-0.39	1	0.11	919	99.46
0.39-0.40	0	0	919	99.46
0.40-0.41	0	0	919	99.46
0.41-0.42	0	0	919	99.46
0.42-0.43	0	0	919	99.46
0.43-0.44	1	0.11	920	99.57
0.44-0.45	1	0.11	921	99.68
0.45-0.46	0	0	921	99.68
0.46-0.47	1	0.11	922	99.78
0.47-0.48	0	0	922	99.78
0.48-0.49	0	0	922	99.78
0.49-0.50	0	0	922	99.78
0.50-0.51	0	0	922	99.78
0.51-0.52	0	0	922	99.78
0.52-0.53	0	0	922	99.78
0.53-0.54	0	0	922	99.78
0.54-0.55	0	0	922	99.78
0.55-0.56	0	0	922	99.78
0.56-0.57	0	0	922	99.78
0.57-0.58	0	0	922	99.78
0.58-0.59	1	0.11	923	99.89
0.59-0.60	0	0	923	99.89
0.60-0.61	0	0	923	99.89
0.61-0.62	0	0	923	99.89
0.62-0.63	0	0	923	99.89
0.63-0.64	0	0	923	99.89
0.64-0.65	0	0	923	99.89
0.65-0.66	0	0	923	99.89
0.66-0.67	0	0	923	99.89
0.67-0.68	0	0	923	99.89
0.68-0.69	0	0	923	99.89
0.69-0.70	0	0	923	99.89
0.70-0.71	0	0	923	99.89
0.71-0.72	0	0	923	99.89
0.72-0.73	0	0	923	99.89
0.73-0.74	0	0	923	99.89
0.74-0.75	0	0	923	99.89
0.75-0.76	0	0	923	99.89
0.76-0.77	0	0	923	99.89
0.77-0.78	0	0	923	99.89
0.78-0.79	0	0	923	99.89
0.79-0.80	0	0	923	99.89
0.80-0.81	0	0	923	99.89
0.81-0.82	0	0	923	99.89
0.82-0.83	0	0	923	99.89
0.83-0.84	0	0	923	99.89
0.84-0.85	0	0	923	99.89
0.85-0.86	0	0	923	99.89
0.86-0.87	0	0	923	99.89
0.87-0.88	0	0	923	99.89
0.88-0.89	0	0	923	99.89
0.89-0.90	0	0	923	99.89
0.90-0.91	0	0	923	99.89
0.91-0.92	0	0	923	99.89
0.92-0.93	0	0	923	99.89
0.93-0.94	0	0	923	99.89
0.94-0.95	0	0	923	99.89
0.95-0.96	0	0	923	99.89
0.96-0.97	0	0	923	99.89
0.97-0.98	0	0	923	99.89
0.98-0.99	1	0.11	924	100

TAN 19

Data sheet

Fig 1-104.

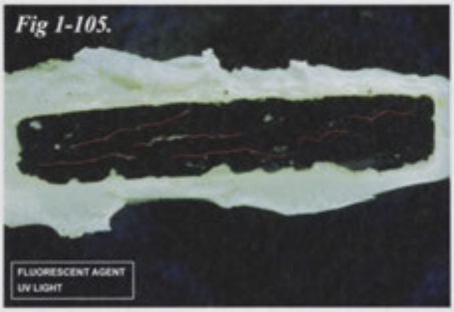


Fig 1-105.

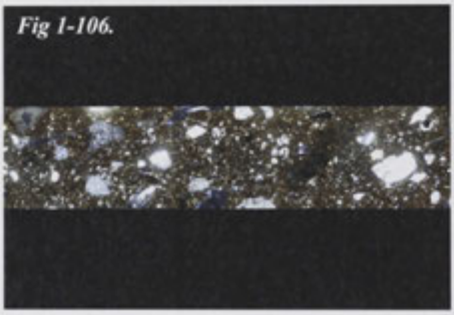


Fig 1-106.

Table 1-39. Temper data.

Number of Objects	Area Fraction	Area (mm²)	Measured Area (mm²)
946	0.161	1.27	7.888

Feature	Mean	SD	Minimum	Maximum
Area (mm²)	N/A	N/A	N/A	N/A
Equivalent Diameter (mm)	N/A	N/A	N/A	N/A
Circularity	N/A	N/A	N/A	N/A
Max Feret (mm²)	N/A	N/A	N/A	N/A

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.01-0.02	533	56.34	533	56.34
0.02-0.03	194	20.51	727	76.85
0.03-0.04	86	9.09	813	85.94
0.04-0.05	40	4.23	853	90.17
0.05-0.06	25	2.64	878	92.81
0.06-0.07	16	1.69	894	94.5
0.07-0.08	9	0.95	903	95.45
0.08-0.09	4	0.42	907	95.88
0.09-0.10	1	0.11	908	95.98
0.10-0.11	3	0.32	911	96.3
0.11-0.12	2	0.21	913	96.51
0.12-0.13	2	0.21	915	96.72
0.13-0.14	3	0.32	918	97.04
0.14-0.15	3	0.32	921	97.36
0.15-0.16	0	0	921	97.36
0.16-0.17	2	0.21	923	97.57
0.17-0.18	2	0.21	925	97.78
0.18-0.19	2	0.21	927	97.99
0.19-0.20	1	0.11	928	98.1
0.20-0.21	1	0.11	929	98.2
0.21-0.22	0	0	929	98.2
0.22-0.23	1	0.11	930	98.31

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.23-0.24	1	0.11	931	98.41
0.24-0.25	3	0.32	934	98.73
0.25-0.26	2	0.21	936	98.94
0.26-0.27	0	0	936	98.94
0.27-0.28	1	0.11	937	99.05
0.28-0.29	0	0	937	99.05
0.29-0.30	1	0.11	938	99.15
0.30-0.31	1	0.11	939	99.26
0.31-0.32	0	0	939	99.26
0.32-0.33	0	0	939	99.26
0.33-0.34	0	0	939	99.26
0.34-0.35	0	0	939	99.26
0.35-0.36	2	0.21	941	99.47
0.36-0.37	0	0	941	99.47
0.37-0.38	1	0.11	942	99.58
0.38-0.39	0	0	942	99.58
0.39-0.40	0	0	942	99.58
0.40-0.41	0	0	942	99.58
0.41-0.42	0	0	942	99.58
0.42-0.43	0	0	942	99.58
0.43-0.44	0	0	942	99.58
0.44-0.45	0	0	942	99.58
0.45-0.46	0	0	942	99.58
0.46-0.47	0	0	942	99.58
0.47-0.48	0	0	942	99.58
0.48-0.49	0	0	942	99.58
0.49-0.50	0	0	942	99.58
0.50-0.51	1	0.11	943	99.68
0.51-0.52	0	0	943	99.68
0.52-0.53	0	0	943	99.68
0.53-0.54	0	0	943	99.68
0.54-0.55	0	0	943	99.68
0.55-0.56	0	0	943	99.68
0.56-0.57	1	0.11	944	99.79
0.57-0.58	0	0	944	99.79
0.58-0.59	1	0.11	945	99.89
0.59-0.60	1	0.11	946	100

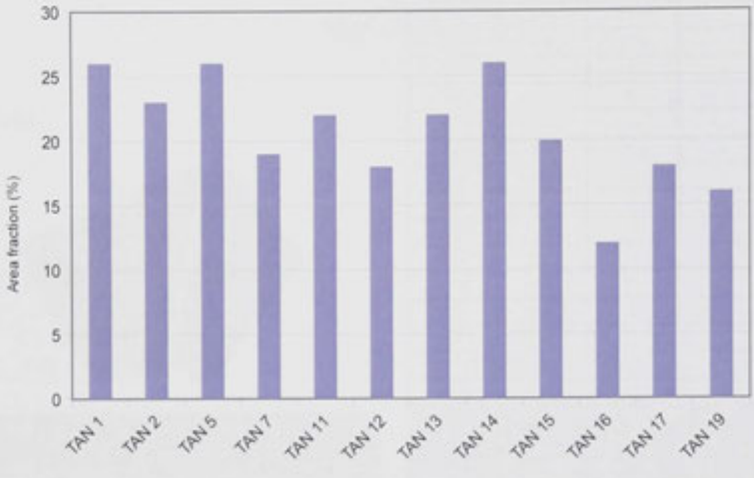


Fig 1-107. Amount of temper in the clay.

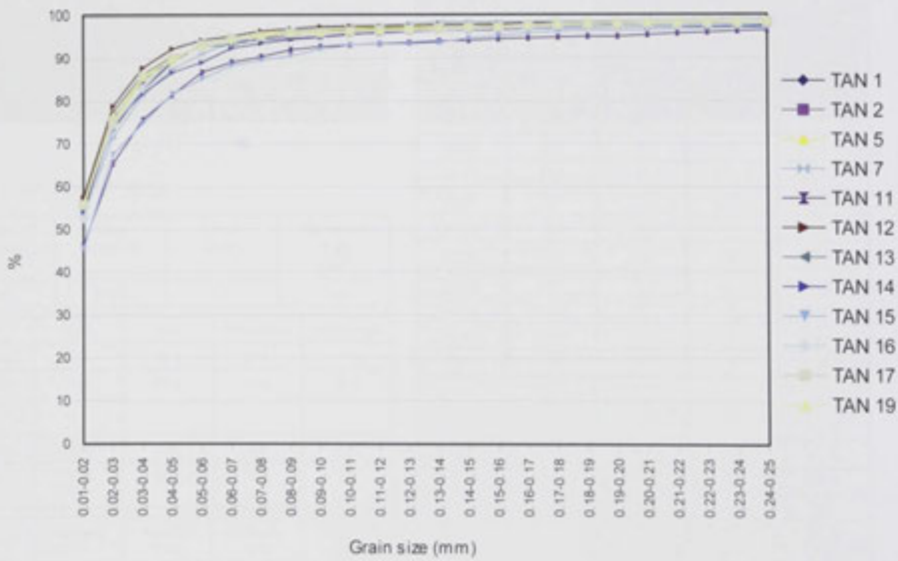


Fig 1-108. Cumulative grain size distribution.

Table 1-40. Result of pore line analysis..

Lab. no.	Maufacturing technique
TAN 1	Paddle and anvil
TAN 2	Paddle and anvil
TAN 4	Not Analysed
TAN 5	Coiling
TAN 7	Paddle and anvil
TAN 9	Not Analysed
TAN 10	Not Analysed
TAN11	Paddle and anvil
TAN 12	Paddle and anvil
TAN 13	Paddle and anvil
TAN 14	Paddle and anvil
TAN 15	Paddle and anvil
TAN 16	Paddle and anvil
TAN 17	Coiling/Paddle and anvil?
TAN 19	Paddle and anvil

Table 1-41. Thermal test results.

	Temperature (°C)	20	100	200	300	400	500	600	700	800	900	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500
TAN 1	Hue	2		2	2	2	2	2	2	2	1	1		1	1	1						
	Value	6		6	6	6	6	7	7	6	6	6		5	5	3						
	Chroma	6		6	6	6	6	6	6	6	8	8		8	6	2						
	Phase									**F**							D		F			
TAN 2	Hue	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2					
	Value	7		7	7	7	7	7	6	6	6	7	6	5	4	4	3					
	Chroma	8		8	8	8	8	8	8	8	8	8	8	8	4	3	2					
	Phase											**F**						S				
TAN4	Hue	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2				
	Value	7		7	7	6	6	6	6	7	7	6	6	6	5	4	3	3				
	Chroma	8		8	8	8	8	8	7	7	8	8	8	8	4	3	3	1				
	Phase										**F**							D	S			
TAN7	Hue	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2				
	Value	7		7	7	6	6	6	6	6	7	7	7	7	6	4	4	4				
	Chroma	8		8	8	6	8	8	8	8	8	8	8	8	8	3	2	2				
	Phase										**F**							D	S			
TAN 11	Hue	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	1				
	Value	6		7	6	5	6	6	7	7	7	6	6	6	5	4	3	2				
	Chroma	8		6	6	8	6	6	6	6	6	8	8	8	8	4	2	2				
	Phase											**F**						D	S			

D = Dilation
S = Sintering
F = Fluid

F = Firing temperature

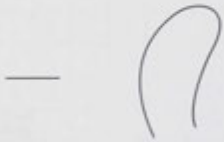
Nagsabaran, Philippines (NAG)

NAG 1

Data sheet

Fig 1-109.

1:1



1:4

ø34 cm

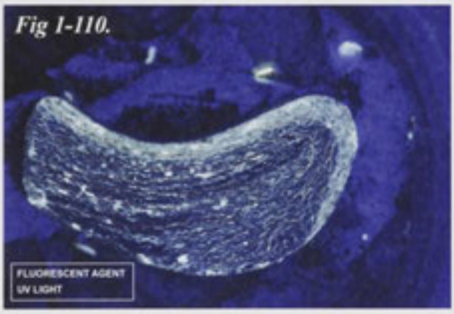


Fig 1-110.

Fig 1-111.

Table 1-42. Temper data.

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.02-0.03	1264	27.8	1264	27.8
0.03-0.04	682	15	1946	42.81
0.04-0.05	473	10.4	2419	53.21
0.05-0.06	286	6.29	2705	59.5
0.06-0.07	188	4.14	2893	63.64
0.07-0.08	199	4.38	3092	68.02
0.08-0.09	141	3.1	3233	71.12
0.09-0.1	123	2.71	3356	73.82
0.1-0.11	118	2.6	3474	76.42
0.11-0.12	107	2.35	3581	78.77
0.12-0.13	81	1.78	3662	80.55
0.13-0.14	93	2.05	3755	82.6
0.14-0.15	76	1.67	3831	84.27
0.15-0.16	61	1.34	3892	85.61
0.16-0.17	86	1.89	3978	87.51
0.17-0.18	53	1.17	4031	88.67
0.18-0.19	52	1.14	4083	89.82
0.19-0.2	43	0.95	4126	90.76
0.2-0.21	47	1.03	4173	91.79
0.21-0.22	45	0.99	4218	92.78
0.22-0.23	32	0.7	4250	93.49
0.23-0.24	32	0.7	4282	94.19

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.24-0.25	30	0.66	4312	94.85
0.25-0.26	23	0.51	4335	95.36
0.26-0.27	13	0.29	4348	95.64
0.27-0.28	14	0.31	4362	95.95
0.28-0.29	22	0.48	4384	96.44
0.29-0.3	19	0.42	4403	96.85
0.3-0.31	14	0.31	4417	97.16
0.31-0.32	16	0.35	4433	97.51
0.32-0.33	12	0.26	4445	97.78
0.33-0.34	10	0.22	4455	98
0.34-0.35	14	0.31	4469	98.31
0.35-0.36	6	0.13	4475	98.44
0.36-0.37	10	0.22	4485	98.66
0.37-0.38	5	0.11	4490	98.77
0.38-0.39	2	0.04	4492	98.81
0.39-0.4	6	0.13	4498	98.94
0.4-0.41	1	0.02	4499	98.97
0.41-0.42	8	0.18	4507	99.14
0.42-0.43	6	0.13	4513	99.27
0.43-0.44	2	0.04	4515	99.32
0.44-0.45	6	0.13	4521	99.45
0.45-0.46	0	0	4521	99.45
0.46-0.47	4	0.09	4525	99.54
0.47-0.48	6	0.13	4531	99.67
0.48-0.49	2	0.04	4533	99.71
0.49-0.5	1	0.02	4534	99.74
0.5-0.51	1	0.02	4535	99.76
0.51-0.52	2	0.04	4537	99.8
0.52-0.53	3	0.07	4540	99.87
0.53-0.54	0	0	4540	99.87
0.54-0.55	0	0	4540	99.87
0.55-0.56	2	0.04	4542	99.91
0.56-0.57	0	0	4542	99.91
0.57-0.58	1	0.02	4543	99.93
0.58-0.59	1	0.02	4544	99.96
0.59-0.6	1	0.02	4545	99.98
0.6-0.61	1	0.02	4546	100

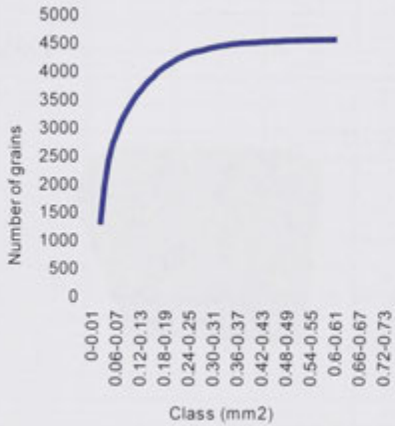


Fig 1-112. Cumulative amount of grains.

NAG 2

Data sheet

Fig 1-113.

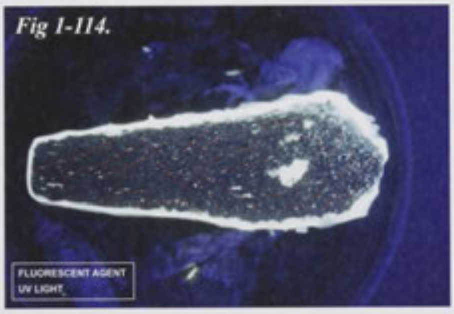


Fig 1-114.

Fig 1-115.

Table 1-43. Temper data.

Number of Objects	Area Fraction	Area (mm²)	Measured Area (mm²)
5505	0.084	162.24	N/A

Feature	Mean	SD	Minimum	Maximum
Area (mm²)	0.002	0.01	0.00007	0.17
Equivalent Diameter (mm)	0.04	0.04	0.01	0.46
Circularity	0.659	0.197	0.022	1
Max Feret (mm²)	0.06	0.06	0.02	0.93

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.02-0.03	1847	33.55	1847	33.55
0.03-0.04	918	16.68	2765	50.23
0.04-0.05	610	11.08	3375	61.31
0.05-0.06	410	7.45	3785	68.76
0.06-0.07	291	5.29	4076	74.04
0.07-0.08	235	4.27	4311	78.31
0.08-0.09	199	3.61	4510	81.93
0.09-0.1	160	2.91	4670	84.83
0.1-0.11	129	2.34	4799	87.18
0.11-0.12	122	2.22	4921	89.39
0.12-0.13	79	1.44	5000	90.83
0.13-0.14	79	1.44	5079	92.26
0.14-0.15	47	0.85	5126	93.12
0.15-0.16	51	0.93	5177	94.04
0.16-0.17	49	0.89	5226	94.93
0.17-0.18	40	0.73	5266	95.66
0.18-0.19	28	0.51	5294	96.17

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.19-0.2	29	0.53	5323	96.69
0.2-0.21	24	0.44	5347	97.13
0.21-0.22	23	0.42	5370	97.55
0.22-0.23	21	0.38	5391	97.93
0.23-0.24	7	0.13	5398	98.06
0.24-0.25	9	0.16	5407	98.22
0.25-0.26	9	0.16	5416	98.38
0.26-0.27	9	0.16	5425	98.55
0.27-0.28	9	0.16	5434	98.71
0.28-0.29	11	0.2	5445	98.91
0.29-0.3	6	0.11	5451	99.02
0.3-0.31	7	0.13	5458	99.15
0.31-0.32	3	0.05	5461	99.2
0.32-0.33	1	0.02	5462	99.22
0.33-0.34	4	0.07	5466	99.29
0.34-0.35	2	0.04	5468	99.33
0.35-0.36	3	0.05	5471	99.38
0.36-0.37	4	0.07	5475	99.46
0.37-0.38	4	0.07	5479	99.53
0.38-0.39	1	0.02	5480	99.55
0.39-0.4	1	0.02	5481	99.56
0.4-0.41	1	0.02	5482	99.58
0.41-0.42	2	0.04	5484	99.62
0.42-0.43	0	0	5484	99.62
0.43-0.44	3	0.05	5487	99.67
0.44-0.45	3	0.05	5490	99.73
0.45-0.46	2	0.04	5492	99.76
0.46-0.47	1	0.02	5493	99.78
0.47-0.48	2	0.04	5495	99.82
0.48-0.49	0	0	5495	99.82
0.49-0.5	2	0.04	5497	99.85
0.5-0.51	0	0	5497	99.85
0.51-0.52	1	0.02	5498	99.87
0.52-0.53	0	0	5498	99.87
0.53-0.54	1	0.02	5499	99.89
0.54-0.55	0	0	5499	99.89
0.55-0.56	0	0	5499	99.89
0.56-0.57	0	0	5499	99.89
0.57-0.58	0	0	5499	99.89
0.58-0.59	1	0.02	5500	99.91
0.59-0.6	1	0.02	5501	99.93
0.6-0.61	0	0	5501	99.93
0.61-0.62	0	0	5501	99.93
0.62-0.63	0	0	5501	99.93
0.63-0.64	0	0	5501	99.93
0.64-0.65	0	0	5501	99.93
0.65-0.66	0	0	5501	99.93
0.66-0.67	1	0.02	5502	99.95
0.67-0.68	0	0	5502	99.95
0.68-0.69	1	0.02	5503	99.96
0.69-0.7	0	0	5503	99.96
0.7-0.71	0	0	5503	99.96
0.71-0.72	0	0	5503	99.96
0.72-0.73	0	0	5503	99.96
0.73-0.74	0	0	5503	99.96
0.74-0.75	0	0	5503	99.96
0.75-0.76	0	0	5503	99.96
0.76-0.77	1	0.02	5504	99.98
0.77-0.78	0	0	5504	99.98
0.78-0.79	0	0	5504	99.98
0.79-0.8	0	0	5504	99.98
0.8-0.81	0	0	5504	99.98
0.81-0.82	0	0	5504	99.98
0.82-0.83	0	0	5504	99.98
0.83-0.84	0	0	5504	99.98
0.84-0.85	0	0	5504	99.98
0.85-0.86	0	0	5504	99.98
0.86-0.87	0	0	5504	99.98
0.87-0.88	0	0	5504	99.98
0.88-0.89	0	0	5504	99.98
0.89-0.9	0	0	5504	99.98
0.9-0.91	0	0	5504	99.98
0.91-0.92	0	0	5504	99.98
0.92-0.93	1	0.02	5505	100

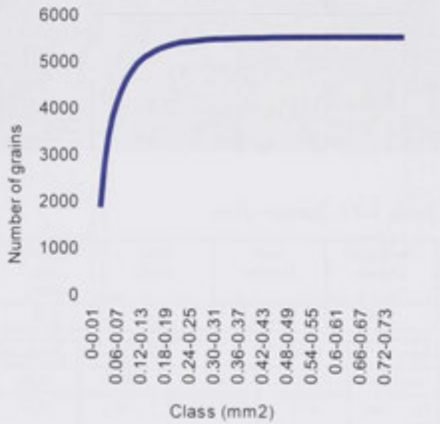


Fig 1-116. Cumulative amount of grains.

NAG 3

Data sheet

Fig 1-117.

1:1

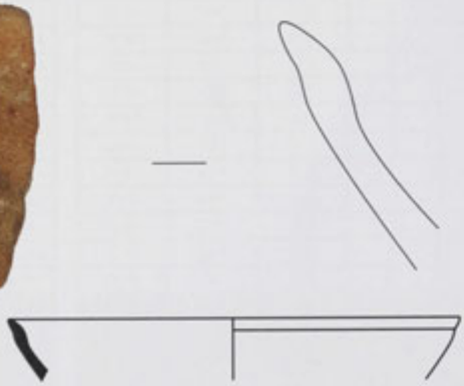


Fig 1-118.

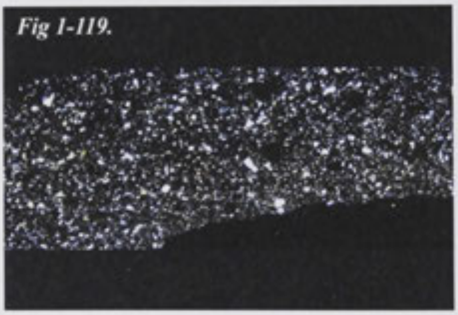


Fig 1-119.

Table 1-44. Temper data.

Number of Objects	Area Fraction	Area (mm²)	Measured Area (mm²)
5278	0.123	164.05	N/A

Feature	Mean	SD	Minimum	Maximum
Area (mm²)	0.004	0.01	0.00007	0.21
Equivalent Diameter (mm)	0.05	0.05	0.01	0.52
Circularity	0.758	0.165	0.153	1
Max Feret (mm²)	0.07	0.07	0.02	0.86

Class (mm²)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.02-0.03	1214	23	1214	23
0.03-0.04	823	15.59	2037	38.59
0.04-0.05	620	11.75	2657	50.34
0.05-0.06	418	7.92	3075	58.26
0.06-0.07	369	6.99	3444	65.25
0.07-0.08	228	4.32	3672	69.57
0.08-0.09	209	3.96	3881	73.53
0.09-0.1	193	3.66	4074	77.19
0.1-0.11	164	3.11	4238	80.3
0.11-0.12	125	2.37	4363	82.66
0.12-0.13	107	2.03	4470	84.69
0.13-0.14	115	2.18	4585	86.87

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.14-0.15	89	1.69	4674	88.56
0.15-0.16	90	1.71	4764	90.26
0.16-0.17	73	1.38	4837	91.64
0.17-0.18	52	0.99	4889	92.63
0.18-0.19	64	1.21	4953	93.84
0.19-0.2	38	0.72	4991	94.56
0.2-0.21	35	0.66	5026	95.23
0.21-0.22	29	0.55	5055	95.77
0.22-0.23	26	0.49	5081	96.27
0.23-0.24	15	0.28	5096	96.55
0.24-0.25	18	0.34	5114	96.89
0.25-0.26	21	0.4	5135	97.29
0.26-0.27	16	0.3	5151	97.59
0.27-0.28	15	0.28	5166	97.88
0.28-0.29	16	0.3	5182	98.18
0.29-0.3	8	0.15	5190	98.33
0.3-0.31	8	0.15	5198	98.48
0.31-0.32	13	0.25	5211	98.73
0.32-0.33	11	0.21	5222	98.94
0.33-0.34	7	0.13	5229	99.07
0.34-0.35	4	0.08	5233	99.15
0.35-0.36	2	0.04	5235	99.19
0.36-0.37	4	0.08	5239	99.26
0.37-0.38	7	0.13	5246	99.39
0.38-0.39	2	0.04	5248	99.43
0.39-0.4	2	0.04	5250	99.47
0.4-0.41	3	0.06	5253	99.53
0.41-0.42	4	0.08	5257	99.6
0.42-0.43	1	0.02	5258	99.62
0.43-0.44	2	0.04	5260	99.66
0.44-0.45	2	0.04	5262	99.7
0.45-0.46	1	0.02	5263	99.72
0.46-0.47	2	0.04	5265	99.75
0.47-0.48	5	0.09	5270	99.85
0.48-0.49	2	0.04	5272	99.89
0.49-0.5	1	0.02	5273	99.91
0.5-0.51	0	0	5273	99.91
0.51-0.52	0	0	5273	99.91
0.52-0.53	1	0.02	5274	99.92
0.53-0.54	0	0	5274	99.92
0.54-0.55	0	0	5274	99.92
0.55-0.56	1	0.02	5275	99.94
0.56-0.57	0	0	5275	99.94
0.57-0.58	0	0	5275	99.94
0.58-0.59	1	0.02	5276	99.96
0.59-0.6	1	0.02	5277	99.98
0.6-0.61	0	0	5277	99.98
0.61-0.62	0	0	5277	99.98
0.62-0.63	0	0	5277	99.98
0.63-0.64	0	0	5277	99.98
0.64-0.65	0	0	5277	99.98
0.65-0.66	0	0	5277	99.98
0.66-0.67	0	0	5277	99.98
0.67-0.68	0	0	5277	99.98
0.68-0.69	0	0	5277	99.98
0.69-0.7	0	0	5277	99.98
0.7-0.71	0	0	5277	99.98
0.71-0.72	0	0	5277	99.98
0.72-0.73	0	0	5277	99.98
0.73-0.74	0	0	5277	99.98
0.74-0.75	0	0	5277	99.98
0.75-0.76	0	0	5277	99.98
0.76-0.77	0	0	5277	99.98
0.77-0.78	0	0	5277	99.98
0.78-0.79	0	0	5277	99.98
0.79-0.8	0	0	5277	99.98
0.8-0.81	0	0	5277	99.98
0.81-0.82	0	0	5277	99.98
0.82-0.83	0	0	5277	99.98
0.83-0.84	0	0	5277	99.98
0.84-0.85	0	0	5277	99.98
0.85-0.86	1	0.02	5278	100

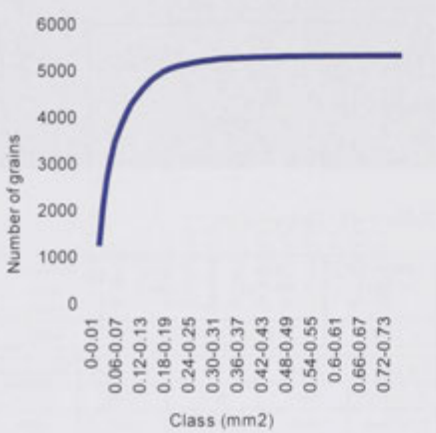


Fig 1-120. Cumulative amount of grains.

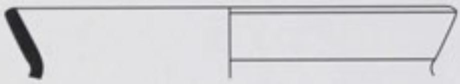
NAG 4

Data sheet

Fig 1-121.

Fig 1-122.

1:4



ø32 cm

Table 1-45. Temper data.

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
5601	0.204	79.2	148.25

Feature	Mean	SD	Minimum	Maximum
Area (mm^2)	0.003	0.01	0.00007	0.35
Equivalent Diameter (mm)	0.04	0.04	0.01	0.66
Circularity	0.863	0.132	0.145	1
Max Feret (mm^2)	0.06	0.06	0.02	0.93

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	1512	27	1512	27
0.03-0.04	1253	22.37	2765	49.37
0.04-0.05	926	16.53	3691	65.9
0.05-0.06	562	10.03	4253	75.93
0.06-0.07	340	6.07	4593	82
0.07-0.08	234	4.18	4827	86.18
0.08-0.09	163	2.91	4990	89.09
0.09-0.1	113	2.02	5103	91.11
0.1-0.11	70	1.25	5173	92.36

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.11-0.12	54	0.96	5227	93.32
0.12-0.13	55	0.98	5282	94.3
0.13-0.14	31	0.55	5313	94.86
0.14-0.15	26	0.46	5339	95.32
0.15-0.16	23	0.41	5362	95.73
0.16-0.17	31	0.55	5393	96.29
0.17-0.18	15	0.27	5408	96.55
0.18-0.19	14	0.25	5422	96.8
0.19-0.2	17	0.3	5439	97.11
0.2-0.21	13	0.23	5452	97.34
0.21-0.22	13	0.23	5465	97.57
0.22-0.23	8	0.14	5473	97.71
0.23-0.24	10	0.18	5483	97.89
0.24-0.25	11	0.2	5494	98.09
0.25-0.26	6	0.11	5500	98.2
0.26-0.27	4	0.07	5504	98.27
0.27-0.28	6	0.11	5510	98.38
0.28-0.29	3	0.05	5513	98.43
0.29-0.3	2	0.04	5515	98.46
0.3-0.31	7	0.12	5522	98.59
0.31-0.32	5	0.09	5527	98.68
0.32-0.33	6	0.11	5533	98.79
0.33-0.34	8	0.14	5541	98.93
0.34-0.35	2	0.04	5543	98.96
0.35-0.36	2	0.04	5545	99
0.36-0.37	6	0.11	5551	99.11
0.37-0.38	4	0.07	5555	99.18
0.38-0.39	4	0.07	5559	99.25
0.39-0.4	1	0.02	5560	99.27
0.4-0.41	3	0.05	5563	99.32
0.41-0.42	4	0.07	5567	99.39
0.42-0.43	4	0.07	5571	99.46
0.43-0.44	4	0.07	5575	99.54
0.44-0.45	2	0.04	5577	99.57
0.45-0.46	2	0.04	5579	99.61
0.46-0.47	0	0	5579	99.61
0.47-0.48	3	0.05	5582	99.66
0.48-0.49	2	0.04	5584	99.7
0.49-0.5	4	0.07	5588	99.77
0.5-0.51	1	0.02	5589	99.79
0.51-0.52	0	0	5589	99.79
0.52-0.53	1	0.02	5590	99.8
0.53-0.54	1	0.02	5591	99.82
0.54-0.55	0	0	5591	99.82
0.55-0.56	2	0.04	5593	99.86
0.56-0.57	0	0	5593	99.86
0.57-0.58	1	0.02	5594	99.88
0.58-0.59	0	0	5594	99.88
0.59-0.6	0	0	5594	99.88
0.6-0.61	1	0.02	5595	99.89
0.61-0.62	0	0	5595	99.89
0.62-0.63	1	0.02	5596	99.91
0.63-0.64	0	0	5596	99.91
0.64-0.65	0	0	5596	99.91
0.65-0.66	0	0	5596	99.91
0.66-0.67	1	0.02	5597	99.93
0.67-0.68	0	0	5597	99.93
0.68-0.69	0	0	5597	99.93
0.69-0.7	0	0	5597	99.93
0.7-0.71	0	0	5597	99.93
0.71-0.72	0	0	5597	99.93
0.72-0.73	0	0	5597	99.93
0.73-0.74	0	0	5597	99.93
0.74-0.75	1	0.02	5598	99.95
0.88-0.89	1	0.02	5599	99.96
0.89-0.9	0	0	5599	99.96
0.9-0.91	1	0.02	5600	99.98
0.91-0.92	0	0	5600	99.98
0.92-0.93	0	0	5600	99.98
0.93-0.94	1	0.02	5601	100

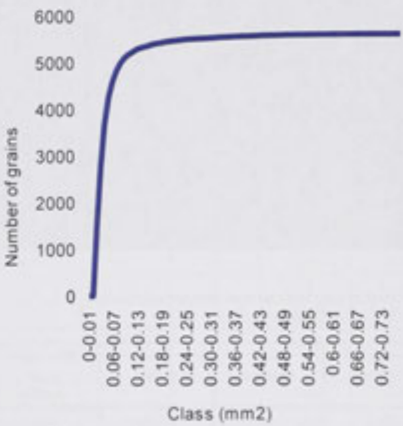


Fig 1-123. Cumulative amount of grains.

NAG 5

Data sheet

Fig 1-124.

Fig 1-125.

Fig 1-126.

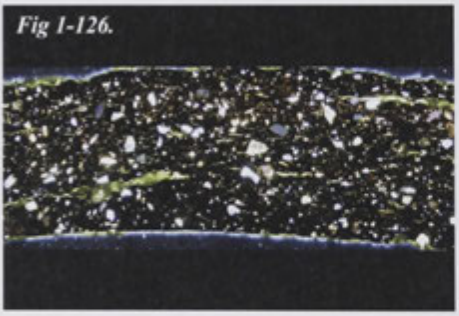


Table 1-46. Temper data.

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
1243	0.095	170.95	N/A

Feature	Mean	SD	Minimum	Maximum
Area (mm^2)	0.01	0.04	0.0001	0.54
Equivalent Diameter (mm)	0.08	0.1	0.01	0.83
Circularity	0.652	0.174	0.125	1
Max Feret (mm^2)	0.12	0.14	0.02	1.17

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.02-0.03	216	17.38	216	17.38
0.03-0.04	162	13.03	378	30.41
0.04-0.05	104	8.37	482	38.78
0.05-0.06	70	5.63	552	44.41
0.06-0.07	53	4.26	605	48.67
0.07-0.08	52	4.18	657	52.86
0.08-0.09	47	3.78	704	56.64
0.09-0.1	47	3.78	751	60.42
0.1-0.11	36	2.9	787	63.31
0.11-0.12	46	3.7	833	67.02
0.12-0.13	33	2.65	866	69.67
0.13-0.14	32	2.57	898	72.24
0.14-0.15	32	2.57	930	74.82
0.15-0.16	29	2.33	959	77.15

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Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.16-0.17	25	2.01	984	79.16
0.17-0.18	13	1.05	997	80.21
0.18-0.19	19	1.53	1016	81.74
0.19-0.2	12	0.97	1028	82.7
0.2-0.21	10	0.8	1038	83.51
0.21-0.22	11	0.88	1049	84.39
0.22-0.23	17	1.37	1066	85.76
0.23-0.24	13	1.05	1079	86.81
0.24-0.25	9	0.72	1088	87.53
0.25-0.26	14	1.13	1102	88.66
0.26-0.27	6	0.48	1108	89.14
0.27-0.28	9	0.72	1117	89.86
0.28-0.29	4	0.32	1121	90.19
0.29-0.3	8	0.64	1129	90.83
0.3-0.31	10	0.8	1139	91.63
0.31-0.32	3	0.24	1142	91.87
0.32-0.33	6	0.48	1148	92.36
0.33-0.34	6	0.48	1154	92.84
0.34-0.35	4	0.32	1158	93.16
0.35-0.36	3	0.24	1161	93.4
0.36-0.37	4	0.32	1165	93.72
0.37-0.38	4	0.32	1169	94.05
0.38-0.39	3	0.24	1172	94.29
0.39-0.4	3	0.24	1175	94.53
0.4-0.41	5	0.4	1180	94.93
0.41-0.42	5	0.4	1185	95.33
0.42-0.43	2	0.16	1187	95.49
0.43-0.44	3	0.24	1190	95.74
0.44-0.45	5	0.4	1195	96.14
0.45-0.46	2	0.16	1197	96.3
0.46-0.47	2	0.16	1199	96.46
0.47-0.48	1	0.08	1200	96.54
0.48-0.49	4	0.32	1204	96.86
0.49-0.5	0	0	1204	96.86
0.5-0.51	1	0.08	1205	96.94
0.51-0.52	5	0.4	1210	97.35
0.52-0.53	2	0.16	1212	97.51
0.53-0.54	0	0	1212	97.51
0.54-0.55	1	0.08	1213	97.59
0.55-0.56	2	0.16	1215	97.75
0.56-0.57	3	0.24	1218	97.99
0.57-0.58	0	0	1218	97.99
0.58-0.59	1	0.08	1219	98.07
0.59-0.6	1	0.08	1220	98.15
0.6-0.61	3	0.24	1223	98.39
0.61-0.62	1	0.08	1224	98.47
0.62-0.63	1	0.08	1225	98.55
0.63-0.64	0	0	1225	98.55
0.64-0.65	1	0.08	1226	98.63
0.65-0.66	3	0.24	1229	98.87

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.66-0.67	0	0	1229	98.87
0.67-0.68	1	0.08	1230	98.95
0.68-0.69	0	0	1230	98.95
0.69-0.7	0	0	1230	98.95
0.7-0.71	1	0.08	1231	99.03
0.71-0.72	0	0	1231	99.03
0.72-0.73	1	0.08	1232	99.12
0.73-0.74	1	0.08	1233	99.2
0.74-0.75	0	0	1233	99.2
0.75-0.76	1	0.08	1234	99.28
0.76-0.77	1	0.08	1235	99.36
0.77-0.78	0	0	1235	99.36
0.78-0.79	0	0	1235	99.36
0.79-0.8	1	0.08	1236	99.44
0.8-0.81	1	0.08	1237	99.52
0.81-0.82	0	0	1237	99.52
0.82-0.83	0	0	1237	99.52
0.83-0.84	0	0	1237	99.52
0.84-0.85	0	0	1237	99.52
0.85-0.86	2	0.16	1239	99.68
0.86-0.87	0	0	1239	99.68
0.87-0.88	0	0	1239	99.68
0.88-0.89	0	0	1239	99.68
0.89-0.9	0	0	1239	99.68
0.9-0.91	0	0	1239	99.68
0.91-0.92	1	0.08	1240	99.76
0.92-0.93	0	0	1240	99.76
0.93-0.94	0	0	1240	99.76
0.94-0.95	0	0	1240	99.76
0.95-0.96	0	0	1240	99.76
0.96-0.97	0	0	1240	99.76
0.97-0.98	0	0	1240	99.76
0.98-0.99	0	0	1240	99.76
0.99-1	0	0	1240	99.76
1-1.01	0	0	1240	99.76
1.01-1.02	1	0.08	1241	99.84
1.02-1.03	0	0	1241	99.84
...				
1.08-1.09	0	0	1241	99.84
1.09-1.1	0	0	1241	99.84
1.1-1.11	1	0.08	1242	99.92
1.11-1.12	0	0	1242	99.92
1.12-1.13	0	0	1242	99.92
1.13-1.14	0	0	1242	99.92
1.14-1.15	0	0	1242	99.92
1.15-1.16	0	0	1242	99.92
1.16-1.17	1	0.08	1243	100

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Data sheet

Fig 1-127.

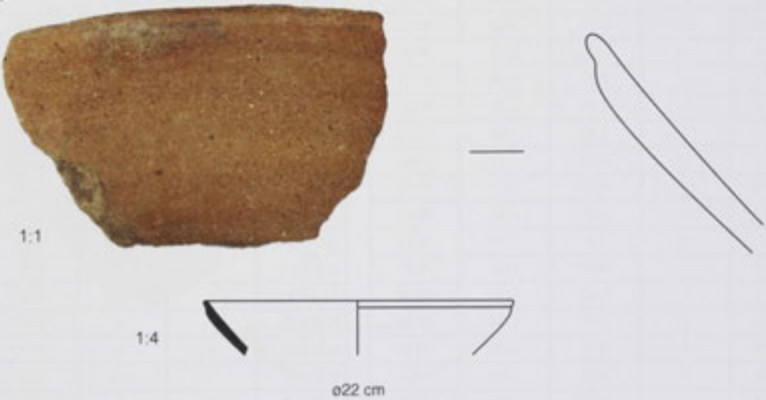

Fig 1-128.

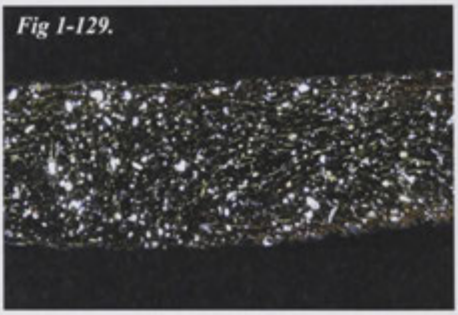

Fig 1-129.

Table 1-47. Temper data.

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
4524	0.131	167.06	N/A

Feature	Mean	SD	Minimum	Maximum
Area (mm^2)	0.005	0.01	0.00009	0.25
Equivalent Diameter (mm)	0.05	0.06	0.01	0.56
Circularity	0.645	0.199	0.089	1
Max Feret (mm^2)	0.08	0.09	0.02	0.96

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.02-0.03	1411	31.19	1411	31.19
0.03-0.04	766	16.93	2177	48.12
0.04-0.05	486	10.74	2663	58.86
0.05-0.06	318	7.03	2981	65.89
0.06-0.07	198	4.38	3179	70.27
0.07-0.08	157	3.47	3336	73.74
0.08-0.09	144	3.18	3480	76.92
0.09-0.1	79	1.75	3559	78.67
0.1-0.11	74	1.64	3633	80.31
0.11-0.12	80	1.77	3713	82.07
0.12-0.13	64	1.41	3777	83.49

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.13-0.14	64	1.41	3841	84.9
0.14-0.15	59	1.3	3900	86.21
0.15-0.16	53	1.17	3953	87.38
0.16-0.17	53	1.17	4006	88.55
0.17-0.18	64	1.41	4070	89.96
0.18-0.19	35	0.77	4105	90.74
0.19-0.2	40	0.88	4145	91.62
0.2-0.21	36	0.8	4181	92.42
0.21-0.22	28	0.62	4209	93.04
0.22-0.23	33	0.73	4242	93.77
0.23-0.24	26	0.57	4268	94.34
0.24-0.25	23	0.51	4291	94.85
0.25-0.26	28	0.62	4319	95.47
0.26-0.27	25	0.55	4344	96.02
0.27-0.28	16	0.35	4360	96.37
0.28-0.29	13	0.29	4373	96.66
0.29-0.3	19	0.42	4392	97.08
0.3-0.31	8	0.18	4400	97.26
0.31-0.32	12	0.27	4412	97.52
0.32-0.33	10	0.22	4422	97.75
0.33-0.34	7	0.15	4429	97.9
0.34-0.35	13	0.29	4442	98.19
0.35-0.36	8	0.18	4450	98.36
0.36-0.37	5	0.11	4455	98.47
0.37-0.38	4	0.09	4459	98.56
0.38-0.39	3	0.07	4462	98.63
0.39-0.4	5	0.11	4467	98.74
0.4-0.41	3	0.07	4470	98.81
0.41-0.42	3	0.07	4473	98.87
0.42-0.43	3	0.07	4476	98.94
0.43-0.44	5	0.11	4481	99.05
0.44-0.45	5	0.11	4486	99.16
0.45-0.46	2	0.04	4488	99.2
0.46-0.47	0	0	4488	99.2
0.47-0.48	5	0.11	4493	99.31
0.48-0.49	2	0.04	4495	99.36
0.49-0.5	2	0.04	4497	99.4
0.5-0.51	1	0.02	4498	99.43
0.51-0.52	2	0.04	4500	99.47
0.52-0.53	1	0.02	4501	99.49
0.53-0.54	0	0	4501	99.49
0.54-0.55	1	0.02	4502	99.51
0.55-0.56	5	0.11	4507	99.62
0.56-0.57	3	0.07	4510	99.69
0.57-0.58	1	0.02	4511	99.71
0.58-0.59	0	0	4511	99.71
0.59-0.6	2	0.04	4513	99.76
0.6-0.61	2	0.04	4515	99.8
0.61-0.62	1	0.02	4516	99.82
0.62-0.63	2	0.04	4518	99.87
0.63-0.64	0	0	4518	99.87
0.64-0.65	1	0.02	4519	99.89
0.65-0.66	1	0.02	4520	99.91
0.66-0.67	0	0	4520	99.91
0.67-0.68	0	0	4520	99.91
0.68-0.69	0	0	4520	99.91
0.69-0.7	1	0.02	4521	99.93
0.7-0.71	0	0	4521	99.93
0.71-0.72	0	0	4521	99.93
0.72-0.73	0	0	4521	99.93
0.73-0.74	0	0	4521	99.93
0.74-0.75	0	0	4521	99.93
0.75-0.76	0	0	4521	99.93
0.76-0.77	0	0	4521	99.93
0.77-0.78	0	0	4521	99.93
0.78-0.79	1	0.02	4522	99.96
0.79-0.8	0	0	4522	99.96
0.8-0.81	1	0.02	4523	99.98
0.95-0.96	1	0.02	4524	100

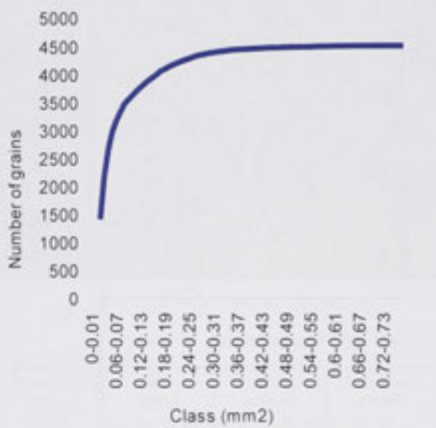

Fig 1-130. Cumulative amount of grains.

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Data sheet

Fig 1-131.

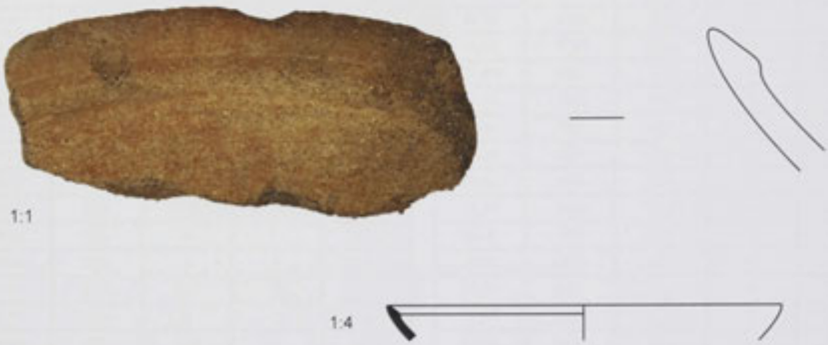

Fig 1-132.

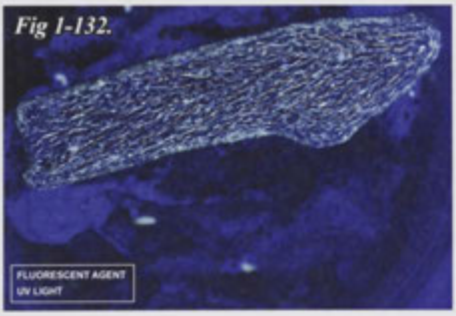

Fig 1-133.

Table 1-48. Temper data.

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
2685	0.179	72.21	147.93

Feature	Mean	SD	Minimum	Maximum
Area (mm^2)	N/A	N/A	N/A	N/A
Equivalent Diameter (mm)	N/A	N/A	N/A	N/A
Circularity	N/A	N/A	N/A	N/A
Max Feret (mm^2)	N/A	N/A	N/A	N/A

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	924	34.41	924	34.41
0.03-0.04	431	16.05	1355	50.47
0.04-0.05	276	10.28	1631	60.74
0.05-0.06	164	6.11	1795	66.85
0.06-0.07	125	4.66	1920	71.51
0.07-0.08	89	3.31	2009	74.82
0.08-0.09	68	2.53	2077	77.36
0.09-0.1	54	2.01	2131	79.37
0.1-0.11	52	1.94	2183	81.3
0.11-0.12	46	1.71	2229	83.02
0.12-0.13	23	0.86	2252	83.87
0.13-0.14	41	1.53	2293	85.4

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.14-0.15	29	1.08	2322	86.48
0.15-0.16	29	1.08	2351	87.56
0.16-0.17	30	1.12	2381	88.68
0.17-0.18	22	0.82	2403	89.5
0.18-0.19	17	0.63	2420	90.13
0.19-0.2	13	0.48	2433	90.61
0.2-0.21	18	0.67	2451	91.28
0.21-0.22	23	0.86	2474	92.14
0.22-0.23	16	0.6	2490	92.74
0.23-0.24	14	0.52	2504	93.26
0.24-0.25	12	0.45	2516	93.71
0.25-0.26	16	0.6	2532	94.3
0.26-0.27	16	0.6	2548	94.9
0.27-0.28	15	0.56	2563	95.46
0.28-0.29	14	0.52	2577	95.98
0.29-0.3	11	0.41	2588	96.39
0.3-0.31	11	0.41	2599	96.8
0.31-0.32	11	0.41	2610	97.21
0.32-0.33	10	0.37	2620	97.58
0.33-0.34	6	0.22	2626	97.8
0.34-0.35	6	0.22	2632	98.03
0.35-0.36	4	0.15	2636	98.18
0.36-0.37	6	0.22	2642	98.4
0.37-0.38	4	0.15	2646	98.55
0.38-0.39	6	0.22	2652	98.77
0.39-0.4	2	0.07	2654	98.85
0.4-0.41	3	0.11	2657	98.96
0.41-0.42	2	0.07	2659	99.03
0.42-0.43	4	0.15	2663	99.18
0.43-0.44	0	0	2663	99.18
0.44-0.45	1	0.04	2664	99.22
0.45-0.46	2	0.07	2666	99.29
0.46-0.47	0	0	2666	99.29
0.47-0.48	3	0.11	2669	99.4
0.48-0.49	1	0.04	2670	99.44
0.49-0.5	0	0	2670	99.44
0.5-0.51	2	0.07	2672	99.52
0.51-0.52	3	0.11	2675	99.63
0.52-0.53	0	0	2675	99.63
0.53-0.54	1	0.04	2676	99.66
0.54-0.55	2	0.07	2678	99.74
0.55-0.56	0	0	2678	99.74
0.56-0.57	0	0	2678	99.74
0.57-0.58	0	0	2678	99.74
0.58-0.59	0	0	2678	99.74
0.59-0.6	1	0.04	2679	99.78
0.6-0.61	0	0	2679	99.78
0.61-0.62	1	0.04	2680	99.81
0.62-0.63	1	0.04	2681	99.85
0.63-0.64	0	0	2681	99.85
0.64-0.65	0	0	2681	99.85
0.65-0.66	1	0.04	2682	99.89
0.66-0.67	0	0	2682	99.89
0.67-0.68	1	0.04	2683	99.93
0.68-0.87	0	0	2683	99.93
0.87-0.88	1	0.04	2684	99.96
0.88-0.89	0	0	2684	99.96
0.89-0.9	0	0	2684	99.96
0.9-0.91	0	0	2684	99.96
0.91-0.92	0	0	2684	99.96
0.92-0.93	0	0	2684	99.96
0.93-0.94	0	0	2684	99.96
0.94-0.95	0	0	2684	99.96
0.95-0.96	0	0	2684	99.96
0.96-0.97	0	0	2684	99.96
0.97-0.98	0	0	2684	99.96
0.98-0.99	0	0	2684	99.96
0.99-1	0	0	2684	99.96
1-1.01	0	0	2684	99.96
1.01-1.02	0	0	2684	99.96
1.02-1.03	0	0	2684	99.96
1.03-1.04	0	0	2684	99.96
1.04-1.05	0	0	2684	99.96
1.05-1.06	1	0.04	2685	100

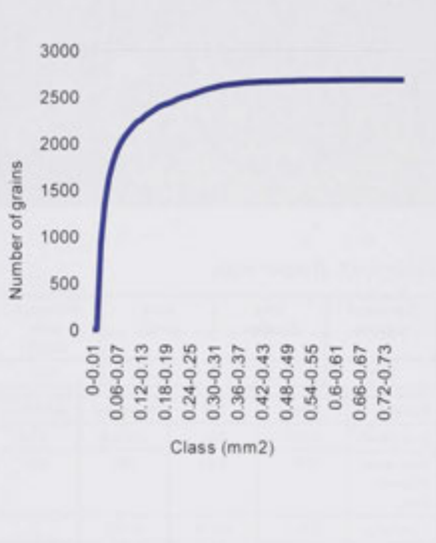

Fig 1-134. Cumulative amount of grains.

NAG 8

Data sheet

Fig 1-135.

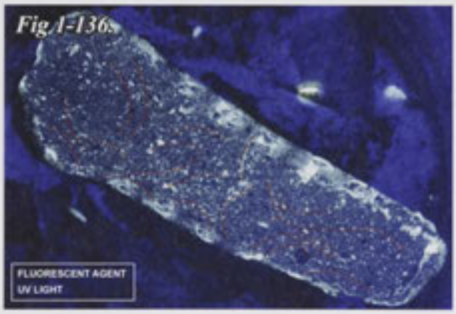

Fig 1-136.

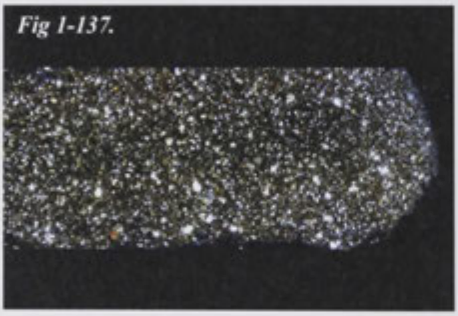

Fig 1-137.

Table 1-49. Temper data.

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
7746	0.116	169.47	N/A

Feature	Mean	SD	Minimum	Maximum
Area (mm^2)	0.003	0.01	0.00008	0.16
Equivalent Diameter (mm)	0.04	0.04	0.01	0.45
Circularity	0.743	0.178	0.143	1
Max Feret (mm^2)	0.06	0.05	0.02	0.56

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.02-0.03	2307	29.78	2307	29.78
0.03-0.04	1328	17.14	3635	46.93
0.04-0.05	958	12.37	4593	59.3
0.05-0.06	620	8	5213	67.3
0.06-0.07	482	6.22	5695	73.52
0.07-0.08	358	4.62	6053	78.14
0.08-0.09	337	4.35	6390	82.49
0.09-0.1	209	2.7	6599	85.19
0.1-0.11	182	2.35	6781	87.54
0.11-0.12	171	2.21	6952	89.75
0.12-0.13	123	1.59	7075	91.34
0.13-0.14	121	1.56	7196	92.9

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.14-0.15	87	1.12	7283	94.02
0.15-0.16	71	0.92	7354	94.94
0.16-0.17	64	0.83	7418	95.77
0.17-0.18	52	0.67	7470	96.44
0.18-0.19	40	0.52	7510	96.95
0.19-0.2	33	0.43	7543	97.38
0.2-0.21	26	0.34	7569	97.71
0.21-0.22	22	0.28	7591	98
0.22-0.23	23	0.3	7614	98.3
0.23-0.24	21	0.27	7635	98.57
0.24-0.25	21	0.27	7656	98.84
0.25-0.26	6	0.08	7662	98.92
0.26-0.27	11	0.14	7673	99.06
0.27-0.28	8	0.1	7681	99.16
0.28-0.29	8	0.1	7689	99.26
0.29-0.3	6	0.08	7695	99.34
0.3-0.31	5	0.06	7700	99.41
0.31-0.32	4	0.05	7704	99.46
0.32-0.33	9	0.12	7713	99.57
0.33-0.34	1	0.01	7714	99.59
0.34-0.35	8	0.1	7722	99.69
0.35-0.36	1	0.01	7723	99.7
0.36-0.37	3	0.04	7726	99.74
0.37-0.38	1	0.01	7727	99.75
0.38-0.39	2	0.03	7729	99.78
0.39-0.4	2	0.03	7731	99.81
0.4-0.41	4	0.05	7735	99.86
0.41-0.42	1	0.01	7736	99.87
0.42-0.43	3	0.04	7739	99.91
0.43-0.44	1	0.01	7740	99.92
0.44-0.45	3	0.04	7743	99.96
0.45-0.46	0	0	7743	99.96
0.46-0.47	0	0	7743	99.96
0.47-0.48	0	0	7743	99.96
0.48-0.49	0	0	7743	99.96
0.49-0.5	0	0	7743	99.96
0.5-0.51	0	0	7743	99.96
0.51-0.52	0	0	7743	99.96
0.52-0.53	0	0	7743	99.96
0.53-0.54	1	0.01	7744	99.97
0.54-0.55	1	0.01	7745	99.99
0.55-0.56	1	0.01	7746	100

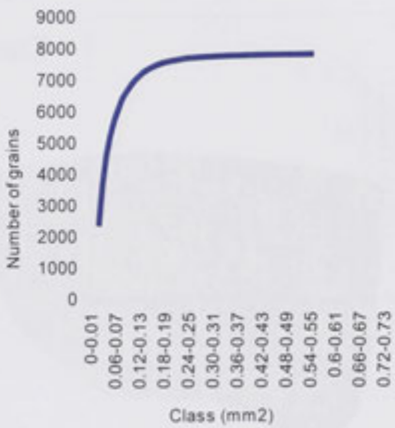

Fig 1-138. Cumulative amount of grains.

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Data sheet

Fig 1-139.

1:4

Fig 1-140.

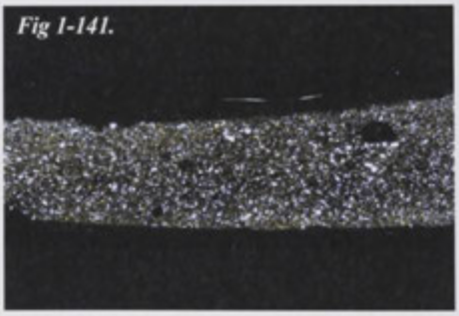

Fig 1-141.

Table 1-50. Temper data.

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
3877	0.096	116.17	N/A

Feature	Mean	SD	Minimum	Maximum
Area (mm^2)	0.003	0.01	0.00008	0.07
Equivalent Diameter (mm)	0.05	0.04	0.01	0.3
Circularity	0.714	0.168	0.146	1
Max Feret (mm^2)	0.07	0.05	0.02	0.52

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.02-0.03	957	24.68	957	24.68
0.03-0.04	574	14.81	1531	39.49
0.04-0.05	461	11.89	1992	51.38
0.05-0.06	304	7.84	2296	59.22
0.06-0.07	230	5.93	2526	65.15
0.07-0.08	212	5.47	2738	70.62
0.08-0.09	175	4.51	2913	75.14
0.09-0.1	161	4.15	3074	79.29
0.1-0.11	143	3.69	3217	82.98
0.11-0.12	100	2.58	3317	85.56

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.12-0.13	101	2.61	3418	88.16
0.13-0.14	93	2.4	3511	90.56
0.14-0.15	53	1.37	3564	91.93
0.15-0.16	48	1.24	3612	93.16
0.16-0.17	54	1.39	3666	94.56
0.17-0.18	33	0.85	3699	95.41
0.18-0.19	28	0.72	3727	96.13
0.19-0.2	19	0.49	3746	96.62
0.2-0.21	26	0.67	3772	97.29
0.21-0.22	16	0.41	3788	97.7
0.22-0.23	20	0.52	3808	98.22
0.23-0.24	12	0.31	3820	98.53
0.24-0.25	7	0.18	3827	98.71
0.25-0.26	10	0.26	3837	98.97
0.26-0.27	4	0.1	3841	99.07
0.27-0.28	5	0.13	3846	99.2
0.28-0.29	5	0.13	3851	99.33
0.29-0.3	3	0.08	3854	99.41
0.3-0.31	2	0.05	3856	99.46
0.31-0.32	4	0.1	3860	99.56
0.32-0.33	3	0.08	3863	99.64
0.33-0.34	4	0.1	3867	99.74
0.34-0.35	2	0.05	3869	99.79
0.35-0.36	0	0	3869	99.79
0.36-0.37	2	0.05	3871	99.85
0.37-0.38	1	0.03	3872	99.87
0.38-0.39	0	0	3872	99.87
0.39-0.4	1	0.03	3873	99.9
0.4-0.41	1	0.03	3874	99.92
0.41-0.42	0	0	3874	99.92
0.42-0.43	1	0.03	3875	99.95
0.43-0.44	0	0	3875	99.95
0.44-0.45	0	0	3875	99.95
0.45-0.46	0	0	3875	99.95
0.46-0.47	0	0	3875	99.95
0.47-0.48	0	0	3875	99.95
0.48-0.49	0	0	3875	99.95
0.49-0.5	1	0.03	3876	99.97
0.5-0.51	0	0	3876	99.97
0.51-0.52	0	0	3876	99.97
0.52-0.53	1	0.03	3877	100

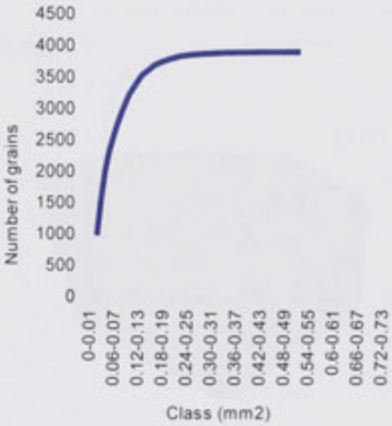

Fig 1-142. Cumulative amount of grains.

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Data sheet

Fig 1-143.

Fig 1-144.

Fig 1-145.

Table 1-51. Temper data.

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
3140	0.165	59.68	148.64

Feature	Mean	SD	Minimum	Maximum
Area (mm^2)	N/A	N/A	N/A	N/A
Equivalent Diameter (mm)	N/A	N/A	N/A	N/A
Circularity	N/A	N/A	N/A	N/A
Max Feret (mm^2)	N/A	N/A	N/A	N/A

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	865	27.55	865	27.55
0.03-0.04	887	28.25	1752	55.8
0.04-0.05	468	14.9	2220	70.7
0.05-0.06	204	6.5	2424	77.2
0.06-0.07	137	4.36	2561	81.56
0.07-0.08	83	2.64	2644	84.2
0.08-0.09	58	1.85	2702	86.05
0.09-0.1	53	1.69	2755	87.74
0.1-0.11	48	1.53	2803	89.27
0.11-0.12	29	0.92	2832	90.19
0.12-0.13	21	0.67	2853	90.86
0.13-0.14	22	0.7	2875	91.56
0.14-0.15	15	0.48	2890	92.04
0.15-0.16	28	0.89	2918	92.93
0.16-0.17	21	0.67	2939	93.6
0.17-0.18	14	0.45	2953	94.04

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.18-0.19	19	0.61	2972	94.65
0.19-0.2	17	0.54	2989	95.19
0.2-0.21	11	0.35	3000	95.54
0.21-0.22	11	0.35	3011	95.89
0.22-0.23	21	0.67	3032	96.56
0.23-0.24	17	0.54	3049	97.1
0.24-0.25	9	0.29	3058	97.39
0.25-0.26	7	0.22	3065	97.61
0.26-0.27	3	0.1	3068	97.71
0.27-0.28	7	0.22	3075	97.93
0.28-0.29	7	0.22	3082	98.15
0.29-0.3	4	0.13	3086	98.28
0.3-0.31	7	0.22	3093	98.5
0.31-0.32	3	0.1	3096	98.6
0.32-0.33	4	0.13	3100	98.73
0.33-0.34	4	0.13	3104	98.85
0.34-0.35	2	0.06	3106	98.92
0.35-0.36	1	0.03	3107	98.95
0.36-0.37	6	0.19	3113	99.14
0.37-0.38	5	0.16	3118	99.3
0.38-0.39	3	0.1	3121	99.39
0.39-0.4	2	0.06	3123	99.46
0.4-0.41	3	0.1	3126	99.55
0.41-0.42	1	0.03	3127	99.59
0.42-0.43	1	0.03	3128	99.62
0.43-0.44	1	0.03	3129	99.65
0.44-0.45	1	0.03	3130	99.68
0.45-0.46	2	0.06	3132	99.75
0.46-0.47	1	0.03	3133	99.78
0.47-0.48	1	0.03	3134	99.81
0.48-0.49	1	0.03	3135	99.84
0.49-0.5	2	0.06	3137	99.9
0.5-0.51	1	0.03	3138	99.94
0.51-0.52	0	0	3138	99.94
0.52-0.53	0	0	3138	99.94
0.53-0.54	0	0	3138	99.94
0.54-0.55	0	0	3138	99.94
0.55-0.56	0	0	3138	99.94
0.56-0.57	0	0	3138	99.94
0.57-0.58	0	0	3138	99.94
0.58-0.59	0	0	3138	99.94
0.59-0.6	0	0	3138	99.94
0.6-0.61	2	0.06	3140	100

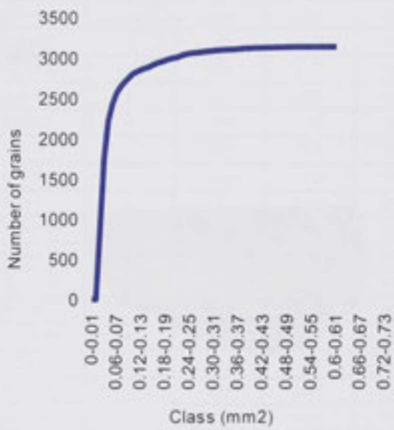
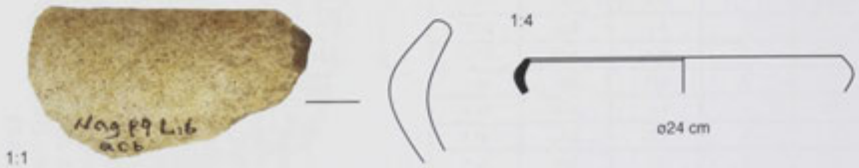


Fig 1-146. Cumulative amount of grains.

NAG 16
Data sheet

Fig 1-147.



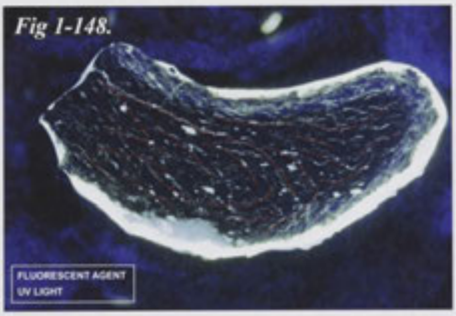


Fig 1-148.

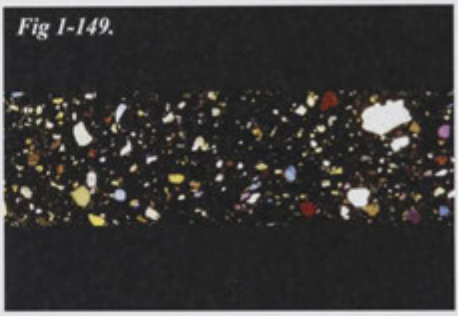


Fig 1-149.

Table 1-52. Temper data.

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
1175	0.216	89.22	148.27

Feature	Mean	SD	Minimum	Maximum
Area (mm^2)	N/A	N/A	N/A	N/A
Equivalent Diameter (mm)	N/A	N/A	N/A	N/A
Circularity	N/A	N/A	N/A	N/A
Max Feret (mm^2)	N/A	N/A	N/A	N/A

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	74	6.3	74	6.3
0.03-0.04	142	12.09	216	18.38
0.04-0.05	185	15.74	401	34.13
0.05-0.06	130	11.06	531	45.19
0.06-0.07	91	7.74	622	52.94
0.07-0.08	63	5.36	685	58.3
0.08-0.09	53	4.51	738	62.81
0.09-0.1	44	3.74	782	66.55
0.1-0.11	44	3.74	826	70.3
0.11-0.12	32	2.72	858	73.02
0.12-0.13	19	1.62	877	74.64
0.13-0.14	26	2.21	903	76.85
0.14-0.15	16	1.36	919	78.21
0.15-0.16	14	1.19	933	79.4
0.16-0.17	13	1.11	946	80.51

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.17-0.18	17	1.45	963	81.96
0.18-0.19	14	1.19	977	83.15
0.19-0.2	18	1.53	995	84.68
0.2-0.21	17	1.45	1012	86.13
0.21-0.22	5	0.43	1017	86.55
0.22-0.23	5	0.43	1022	86.98
0.23-0.24	15	1.28	1037	88.26
0.24-0.25	11	0.94	1048	89.19
0.25-0.26	6	0.51	1054	89.7
0.26-0.27	6	0.51	1060	90.21
0.27-0.28	6	0.51	1066	90.72
0.28-0.29	3	0.26	1069	90.98
0.29-0.3	8	0.68	1077	91.66
0.3-0.31	3	0.26	1080	91.91
0.31-0.32	6	0.51	1086	92.43
0.32-0.33	4	0.34	1090	92.77
0.33-0.34	6	0.51	1096	93.28
0.34-0.35	3	0.26	1099	93.53
0.35-0.36	1	0.09	1100	93.62
0.36-0.37	2	0.17	1102	93.79
0.37-0.38	6	0.51	1108	94.3
0.38-0.39	5	0.43	1113	94.72
0.39-0.4	2	0.17	1115	94.89
0.4-0.41	4	0.34	1119	95.23
0.41-0.42	3	0.26	1122	95.49
0.42-0.43	1	0.09	1123	95.57
0.43-0.44	4	0.34	1127	95.91
0.44-0.45	2	0.17	1129	96.09
0.45-0.46	3	0.26	1132	96.34
0.46-0.47	0	0	1132	96.34
0.47-0.48	2	0.17	1134	96.51
0.48-0.49	2	0.17	1136	96.68
0.49-0.5	2	0.17	1138	96.85
0.5-0.51	1	0.09	1139	96.94
0.51-0.52	1	0.09	1140	97.02
0.52-0.53	2	0.17	1142	97.19
0.53-0.54	2	0.17	1144	97.36
0.54-0.55	0	0	1144	97.36
0.55-0.56	2	0.17	1146	97.53
0.56-0.57	1	0.09	1147	97.62
0.57-0.58	0	0	1147	97.62
0.58-0.59	2	0.17	1149	97.79
0.59-0.6	0	0	1149	97.79
0.6-0.61	2	0.17	1151	97.96
0.61-0.62	1	0.09	1152	98.04
0.62-0.63	0	0	1152	98.04
0.63-0.64	1	0.09	1153	98.13
0.64-0.65	1	0.09	1154	98.21

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.65-0.66	1	0.09	1155	98.3
0.66-0.67	1	0.09	1156	98.38
0.67-0.68	1	0.09	1157	98.47
0.68-0.69	0	0	1157	98.47
0.69-0.7	1	0.09	1158	98.55
0.7-0.71	1	0.09	1159	98.64
0.71-0.72	1	0.09	1160	98.72
0.72-0.73	0	0	1160	98.72
0.73-0.74	0	0	1160	98.72
0.74-0.75	0	0	1160	98.72
0.75-0.76	0	0	1160	98.72
0.76-0.77	1	0.09	1161	98.81
0.77-0.78	0	0	1161	98.81
0.78-0.79	2	0.17	1163	98.98
0.79-0.8	1	0.09	1164	99.06
0.8-0.81	0	0	1164	99.06
0.81-0.82	0	0	1164	99.06
0.82-0.83	1	0.09	1165	99.15
0.83-0.84	0	0	1165	99.15
0.84-0.85	0	0	1165	99.15
0.85-0.86	0	0	1165	99.15
0.86-0.87	2	0.17	1167	99.32
0.87-0.88	1	0.09	1168	99.4
0.88-0.89	0	0	1168	99.4
0.89-0.9	0	0	1168	99.4
0.9-0.91	1	0.09	1169	99.49
0.91-0.92	1	0.09	1170	99.57
0.92-0.93	0	0	1170	99.57
0.93-0.94	0	0	1170	99.57
0.94-0.95	0	0	1170	99.57
0.95-0.96	0	0	1170	99.57
0.96-0.97	0	0	1170	99.57
0.97-0.98	0	0	1170	99.57
0.98-0.99	0	0	1170	99.57
0.99-1	0	0	1170	99.57
1-1.01	0	0	1170	99.57
1.01-1.02	0	0	1170	99.57
1.02-1.03	1	0.09	1171	99.66
1.03-1.04	0	0	1171	99.66
1.04-1.05	0	0	1171	99.66
1.05-1.06	0	0	1171	99.66
1.06-1.07	0	0	1171	99.66
1.07-1.08	0	0	1171	99.66
1.08-1.09	1	0.09	1172	99.74
1.09-1.1	0	0	1172	99.74
1.1-1.11	0	0	1172	99.74
1.11-1.12	0	0	1172	99.74
1.12-1.13	0	0	1172	99.74

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
1.13-1.14	1	0.09	1173	99.83
1.14-1.15	0	0	1173	99.83
1.15-1.16	0	0	1173	99.83
1.16-1.17	0	0	1173	99.83
1.17-1.18	0	0	1173	99.83
1.18-1.19	0	0	1173	99.83
1.19-1.2	0	0	1173	99.83
1.2-1.21	0	0	1173	99.83
1.21-1.22	0	0	1173	99.83
1.22-1.23	0	0	1173	99.83
1.23-1.24	0	0	1173	99.83
1.24-1.25	0	0	1173	99.83
1.25-1.26	0	0	1173	99.83
1.26-1.27	0	0	1173	99.83
1.27-1.28	0	0	1173	99.83
1.28-1.29	0	0	1173	99.83
1.29-1.3	0	0	1173	99.83
1.3-1.31	0	0	1173	99.83
1.31-1.32	0	0	1173	99.83
1.32-1.33	0	0	1173	99.83
1.33-1.34	0	0	1173	99.83
1.34-1.35	0	0	1173	99.83
1.35-1.36	0	0	1173	99.83
1.36-1.37	0	0	1173	99.83
1.37-1.38	1	0.09	1174	99.91
1.38-1.39	0	0	1174	99.91
1.39-1.4	0	0	1174	99.91
1.4-1.41	0	0	1174	99.91
1.41-1.42	0	0	1174	99.91
1.42-1.43	0	0	1174	99.91
1.43-1.44	0	0	1174	99.91
1.44-1.45	0	0	1174	99.91
1.45-1.46	0	0	1174	99.91
1.46-1.47	0	0	1174	99.91
1.47-1.48	0	0	1174	99.91
1.48-1.49	0	0	1174	99.91
1.49-1.5	0	0	1174	99.91
1.5-1.51	0	0	1174	99.91
1.51-1.52	0	0	1174	99.91
1.52-1.53	0	0	1174	99.91
1.53-1.54	0	0	1174	99.91
1.54-1.55	0	0	1174	99.91
1.55-1.56	0	0	1174	99.91
1.56-1.57	0	0	1174	99.91
1.57-1.58	0	0	1174	99.91
1.58-1.59	0	0	1174	99.91
1.59-1.6	0	0	1174	99.91
1.6-1.61	0	0	1174	99.91
1.61-1.62	0	0	1174	99.91
1.62-1.63	0	0	1174	99.91
1.63-1.64	0	0	1174	99.91
1.64-1.65	0	0	1174	99.91
1.65-1.66	0	0	1174	99.91
1.66-1.67	0	0	1174	99.91
1.67-1.68	0	0	1174	99.91
1.68-1.69	0	0	1174	99.91
1.69-1.7	0	0	1174	99.91
1.7-1.71	0	0	1174	99.91
1.71-1.72	0	0	1174	99.91
1.72-1.73	0	0	1174	99.91
...				
2.44-2.45	0	0	1174	99.91
2.45-2.46	0	0	1174	99.91
2.46-2.47	0	0	1174	99.91
2.47-2.48	0	0	1174	99.91
2.48-2.49	0	0	1174	99.91
2.49-2.5	0	0	1174	99.91
2.5-2.51	0	0	1174	99.91
2.51-2.52	0	0	1174	99.91
2.52-2.53	1	0.09	1175	100

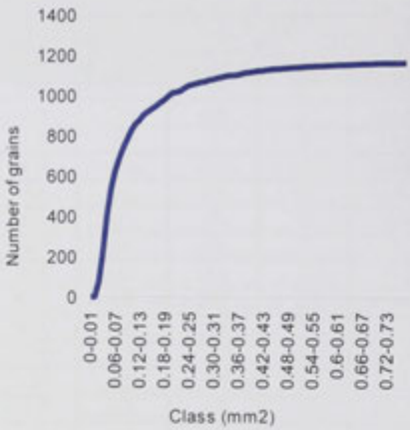


Fig 1-150. Cumulative amount of grains.

NAG 17

Data sheet

Fig 1-152.

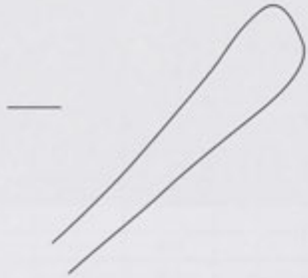


Fig 1-153.

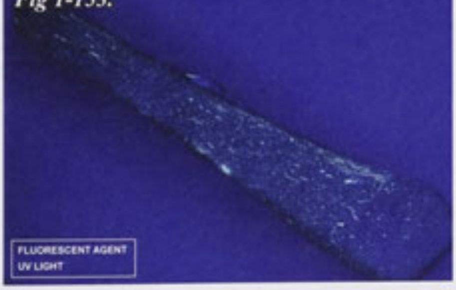


Fig 1-151.

Table 1-53. Temper data.

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
10473	0.141	166.39	N/A

Feature	Mean	SD	Minimum	Maximum
Area (mm^2)	N/A	N/A	N/A	N/A
Equivalent Diameter (mm)	N/A	N/A	N/A	N/A
Circularity	N/A	N/A	N/A	N/A
Max Feret (mm^2)	N/A	N/A	N/A	N/A

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.02-0.03	3243	30.97	3243	30.97
0.03-0.04	1888	18.03	5131	48.99
0.04-0.05	1161	11.09	6292	60.08
0.05-0.06	764	7.29	7056	67.37
0.06-0.07	654	6.24	7710	73.62
0.07-0.08	468	4.47	8178	78.09
0.08-0.09	437	4.17	8615	82.26
0.09-0.1	305	2.91	8920	85.17
0.1-0.11	266	2.54	9186	87.71
0.11-0.12	238	2.27	9424	89.98
0.12-0.13	174	1.66	9598	91.65
0.13-0.14	158	1.51	9756	93.15

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.14-0.15	107	1.02	9863	94.18
0.15-0.16	111	1.06	9974	95.24
0.16-0.17	72	0.69	10046	95.92
0.17-0.18	69	0.66	10115	96.58
0.18-0.19	65	0.62	10180	97.2
0.19-0.2	52	0.5	10232	97.7
0.2-0.21	40	0.38	10272	98.08
0.21-0.22	33	0.32	10305	98.4
0.22-0.23	32	0.31	10337	98.7
0.23-0.24	21	0.2	10358	98.9
0.24-0.25	17	0.16	10375	99.06
0.25-0.26	13	0.12	10388	99.19
0.26-0.27	17	0.16	10405	99.35
0.27-0.28	15	0.14	10420	99.49
0.28-0.29	5	0.05	10425	99.54
0.29-0.3	10	0.1	10435	99.64
0.3-0.31	3	0.03	10438	99.67
0.31-0.32	6	0.06	10444	99.72
0.32-0.33	2	0.02	10446	99.74
0.33-0.34	6	0.06	10452	99.8
0.34-0.35	5	0.05	10457	99.85
0.35-0.36	1	0.01	10458	99.86
0.36-0.37	1	0.01	10459	99.87
0.37-0.38	2	0.02	10461	99.89
0.38-0.39	3	0.03	10464	99.91
0.39-0.4	0	0	10464	99.91
0.4-0.41	0	0	10464	99.91
0.41-0.42	2	0.02	10466	99.93
0.42-0.43	0	0	10466	99.93
0.43-0.44	1	0.01	10467	99.94
0.44-0.45	0	0	10467	99.94
0.45-0.46	1	0.01	10468	99.95
0.46-0.47	1	0.01	10469	99.96
0.47-0.48	2	0.02	10471	99.98
0.48-0.49	0	0	10471	99.98
0.49-0.5	0	0	10471	99.98
0.5-0.51	0	0	10471	99.98
0.51-0.52	0	0	10471	99.98
0.52-0.53	1	0.01	10472	99.99
0.53-0.54	0	0	10472	99.99
0.54-0.55	0	0	10472	99.99
0.55-0.56	0	0	10472	99.99
0.56-0.57	0	0	10472	99.99
0.57-0.58	0	0	10472	99.99
0.58-0.59	0	0	10472	99.99
0.59-0.6	0	0	10472	99.99
0.6-0.61	0	0	10472	99.99
0.61-0.62	0	0	10472	99.99

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.62-0.63	0	0	10472	99.99
0.63-0.64	0	0	10472	99.99
0.64-0.65	0	0	10472	99.99
0.65-0.66	0	0	10472	99.99
0.66-0.67	0	0	10472	99.99
0.67-0.68	0	0	10472	99.99
0.68-0.69	0	0	10472	99.99
0.69-0.7	0	0	10472	99.99
0.7-0.71	0	0	10472	99.99
0.71-0.72	0	0	10472	99.99
0.72-0.73	0	0	10472	99.99
0.73-0.74	0	0	10472	99.99
0.74-0.75	0	0	10472	99.99
0.75-0.76	0	0	10472	99.99
0.76-0.77	0	0	10472	99.99
0.77-0.78	0	0	10472	99.99
0.78-0.79	0	0	10472	99.99
0.79-0.8	0	0	10472	99.99
0.8-0.81	0	0	10472	99.99
0.81-0.82	0	0	10472	99.99

1.01-1.02	1	0.01	10473	100

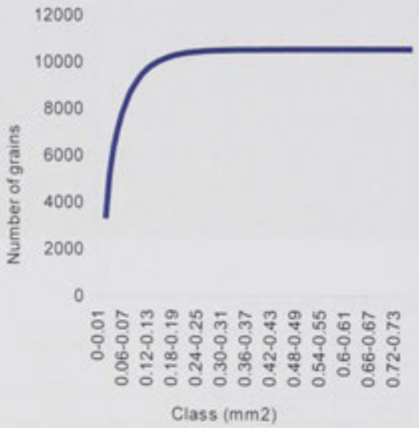


Fig 1-154. Cumulative amount of grains.

NAG 18

Data sheet

Fig 1-156.

1:1

Fig 1-155.

Table 1-54. Temper data.

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
3759	0.174	75.35	148.43

Feature	Mean	SD	Minimum	Maximum
Area (mm^2)	N/A	N/A	N/A	N/A
Equivalent Diameter (mm)	N/A	N/A	N/A	N/A
Circularity	N/A	N/A	N/A	N/A
Max Feret (mm^2)	N/A	N/A	N/A	N/A

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	1148	30.54	1148	30.54
0.03-0.04	766	20.38	1914	50.92
0.04-0.05	496	13.19	2410	64.11
0.05-0.06	277	7.37	2687	71.48
0.06-0.07	178	4.74	2865	76.22
0.07-0.08	147	3.91	3012	80.13
0.08-0.09	101	2.69	3113	82.81
0.09-0.1	89	2.37	3202	85.18
0.1-0.11	78	2.08	3280	87.26
0.11-0.12	68	1.81	3348	89.07
0.12-0.13	45	1.2	3393	90.26
0.13-0.14	46	1.22	3439	91.49
0.14-0.15	36	0.96	3475	92.44
0.15-0.16	45	1.2	3520	93.64
0.16-0.17	21	0.56	3541	94.2
0.17-0.18	14	0.37	3555	94.57
0.18-0.19	26	0.69	3581	95.26
0.19-0.2	15	0.4	3596	95.66
0.2-0.21	12	0.32	3608	95.98
0.21-0.22	16	0.43	3624	96.41
0.22-0.23	15	0.4	3639	96.81
0.23-0.24	6	0.16	3645	96.97
0.24-0.25	7	0.19	3652	97.15
0.25-0.26	16	0.43	3668	97.58
0.26-0.27	10	0.27	3678	97.85
0.27-0.28	6	0.16	3684	98
0.28-0.29	8	0.21	3692	98.22
0.29-0.3	3	0.08	3695	98.3
0.3-0.31	7	0.19	3702	98.48
0.31-0.32	3	0.08	3705	98.56
0.32-0.33	2	0.05	3707	98.62
0.33-0.34	3	0.08	3710	98.7
0.34-0.35	3	0.08	3713	98.78
0.35-0.36	1	0.03	3714	98.8
0.36-0.37	4	0.11	3718	98.91
0.37-0.38	1	0.03	3719	98.94
0.38-0.39	4	0.11	3723	99.04
0.39-0.4	4	0.11	3727	99.15
0.4-0.41	1	0.03	3728	99.18
0.41-0.42	3	0.08	3731	99.26
0.42-0.43	5	0.13	3736	99.39
0.43-0.44	2	0.05	3738	99.44
0.44-0.45	1	0.03	3739	99.47
0.45-0.46	1	0.03	3740	99.49

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.46-0.47	1	0.03	3741	99.52
0.47-0.48	0	0	3741	99.52
0.48-0.49	1	0.03	3742	99.55
0.49-0.5	0	0	3742	99.55
0.5-0.51	3	0.08	3745	99.63
0.51-0.52	0	0	3745	99.63
0.52-0.53	0	0	3745	99.63
0.53-0.54	1	0.03	3746	99.65
0.54-0.55	1	0.03	3747	99.68
0.55-0.56	0	0	3747	99.68
0.56-0.57	0	0	3747	99.68
0.57-0.58	0	0	3747	99.68
0.58-0.59	0	0	3747	99.68
0.59-0.6	0	0	3747	99.68
0.6-0.61	1	0.03	3748	99.71
0.61-0.62	0	0	3748	99.71
0.62-0.63	1	0.03	3749	99.73
0.63-0.64	0	0	3749	99.73
0.64-0.65	1	0.03	3750	99.76
0.65-0.66	1	0.03	3751	99.79
0.66-0.67	1	0.03	3752	99.81
0.67-0.68	0	0	3752	99.81
0.68-0.69	0	0	3752	99.81
0.69-0.7	0	0	3752	99.81
0.7-0.71	0	0	3752	99.81
0.71-0.72	0	0	3752	99.81
0.72-0.73	1	0.03	3753	99.84
0.73-0.74	1	0.03	3754	99.87
0.74-0.75	1	0.03	3755	99.89
0.75-0.76	0	0	3755	99.89
0.76-0.77	1	0.03	3756	99.92
0.77-0.78	0	0	3756	99.92
0.78-0.79	0	0	3756	99.92
0.79-0.8	0	0	3756	99.92
0.8-0.81	0	0	3756	99.92
0.81-0.82	0	0	3756	99.92
0.82-0.83	1	0.03	3757	99.95
0.83-0.84	0	0	3757	99.95
0.84-0.85	0	0	3757	99.95
0.85-0.86	1	0.03	3758	99.97
...				
0.97-0.98	1	0.03	3759	100

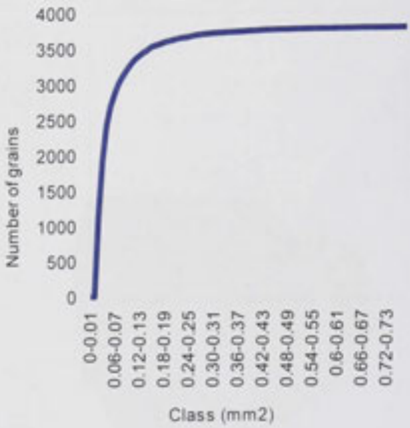


Fig 1-157. Cumulative amount of grains.

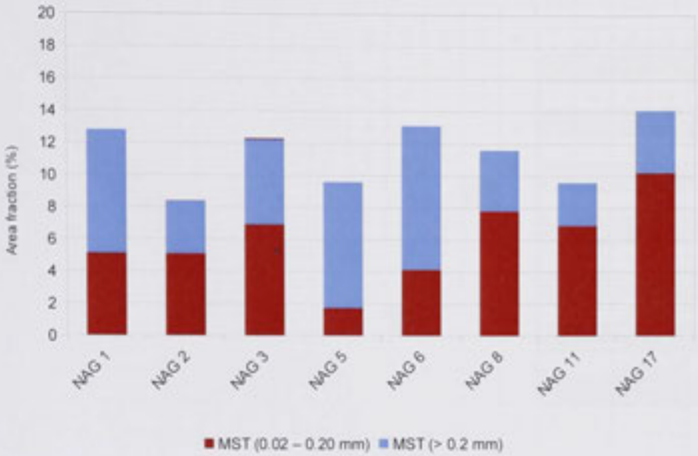


Fig 1-158. Amount of temper in the clay.

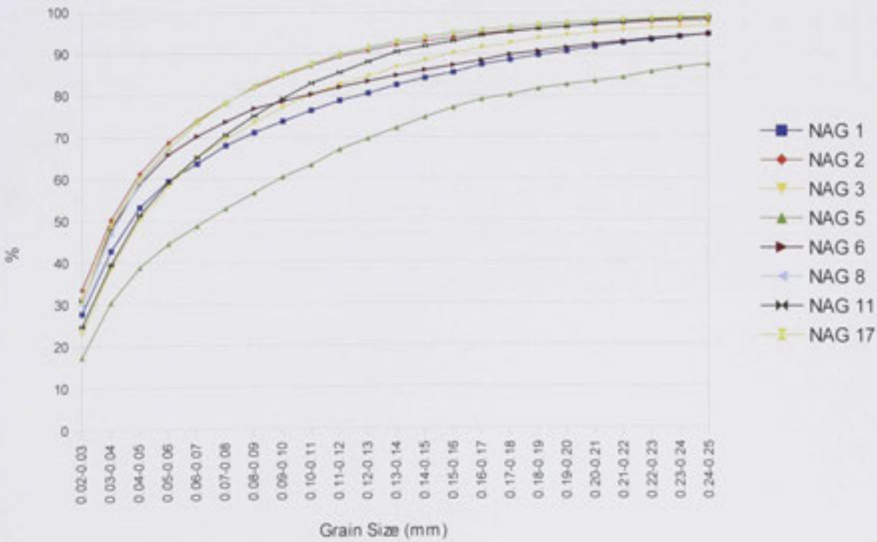


Fig 1-159. Cumulative percentage of grains.

Table 1-55. Result of pore line analysis..

Lab. no.	Maufacturing technique
NAG 1	Paddle and anvil
NAG 2	Coiling
NAG 3	Coiling
NAG 4	Coiling
NAG 5	Coiling
NAG 6	Coiling
NAG 7	Coiling
NAG 8	Coiling
NAG 11	Coiling
NAG 12	Coiling
NAG 16	Coiling
NAG 17	Not analysed
NAG 18	Not analysed

Table 1-56. Thermal test results.

	Temperature (°C)	20	100	200	300	400	500	600	700	800	900	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500
P9 L16	Hue	4		4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	2		
	Value	8		8	7	7	8	8	8	8	8	8	8	8	7	7	7	6	5	4		
	Chroma	4		6	4	3	4	5	6	6	3	4	4	4	3	3	1	1	1	1		
	Phase											F									S-	
P9 L13	Hue	4		4	4	4	4	4	4	4	2	2	2	2	2	2	4	4				
	Value	7		7	6	5	6	7	7	7	7	7	7	4	5	4	3	4				
	Chroma	4		3	4	3	4	6	6	4	8	8	8	6	4	3	2	1				
	Phase									F									S			
P9 L15 BC	Hue	3		2	2	2	2	2	2	3	3	2	2	2	2	2	3					
	Value	5		6	2	4	4	4	5	5	7	7	5	5	4	3	3					
	Chroma	6		6	6	3	6	6	6	6	6	6	6	4	3	3	2					
	Phase									F						B		S				
P10 L14 cc	Hue	3		3	3	3	3	3	3	2	2	2	2	2	2	2	4					
	Value	5		5	5	7	7	7	6	6	5	7	5	5	4	3	3					
	Chroma	8		8	6	6	6	6	6	8	8	8	8	4	4	2	1					
	Phase								F	F	F						B	S				
P10 L14 cc2	Hue	4		4	4	4	4	4	4	4	2	2	2	2	2	1	B					
	Value	7		6	7	7	6	8	8	7	7	7	6	5	4	3						
	Chroma	6		6	6	6	4	6	6	6	6	8	6	6	4	2						
	Phase									F								D				

D = Dilation
S = Sintering
F = Fluid

F = Firing temperature

Ambitle (AME)

AME 1

Data sheet

Fig 1-160.

SCALE 1:1

1:1

1:4

ø22 cm

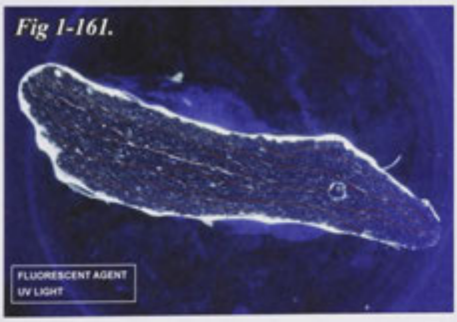


Fig 1-161.

Fig 1-162.

Table 1-57. Temper data

Dark grains

Number of Objects	Area Fraction	Area (mm²)	Measured Area (mm²)
515	0.057	3.29	57.26

Feature	Mean	SD	Minimum	Maximum
Area (mm²)	0.01	0.004	0.00003	0.05
Equivalent Diameter (mm)	0.09	0.03	0.01	0.25

Feature	Mean	SD	Minimum	Maximum
Circularity	0.862	0.092	0.427	1
Max Feret (mm²)	0.11	0.04	0.01	0.3

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0-0.01	0	0	0	0
0.01-0.02	1	0.19	1	0.19
0.02-0.03	3	0.58	4	0.78
0.03-0.04	6	1.17	10	1.94
0.04-0.05	14	2.72	24	4.66
0.05-0.06	21	4.08	45	8.74

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.06-0.07	29	5.63	74	14.37
0.07-0.08	29	5.63	103	20
0.08-0.09	56	10.87	159	30.87
0.09-0.1	50	9.71	209	40.58
0.1-0.11	65	12.62	274	53.2
0.11-0.12	63	12.23	337	65.44
0.12-0.13	53	10.29	390	75.73
0.13-0.14	35	6.8	425	82.52
0.14-0.15	32	6.21	457	88.74
0.15-0.16	18	3.5	475	92.23
0.16-0.17	15	2.91	490	95.15
0.17-0.18	3	0.58	493	95.73
0.18-0.19	10	1.94	503	97.67
0.19-0.2	3	0.58	506	98.25
0.2-0.21	4	0.78	510	99.03
0.21-0.22	2	0.39	512	99.42
0.22-0.23	2	0.39	514	99.81
0.23-0.24	0	0	514	99.81
0.24-0.25	0	0	514	99.81
0.25-0.26	0	0	514	99.81
0.26-0.27	0	0	514	99.81
0.27-0.28	0	0	514	99.81
0.28-0.29	0	0	514	99.81
0.29-0.3	1	0.19	515	100

Light grains

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
989	0.245	14	57.26

Feature	Mean	SD	Minimum	Maximum
Area (mm^2)	0.01	0.02	0.0002	0.44
Equivalent Diameter (mm)	0.12	0.07	0.02	0.75
Circularity	0.813	0.117	0.261	1
Max Feret (mm^2)	0.16	0.09	0.03	0.99

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	1	0.1	1	0.1
0.03-0.04	7	0.71	8	0.81
0.04-0.05	24	2.43	32	3.24
0.05-0.06	42	4.25	74	7.48
0.06-0.07	58	5.86	132	13.35
0.07-0.08	52	5.26	184	18.6

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.08-0.09	64	6.47	248	25.08
0.09-0.1	54	5.46	302	30.54
0.1-0.11	53	5.36	355	35.89
0.11-0.12	50	5.06	405	40.95
0.12-0.13	55	5.56	460	46.51
0.13-0.14	50	5.06	510	51.57
0.14-0.15	55	5.56	565	57.13
0.15-0.16	48	4.85	613	61.98
0.16-0.17	31	3.13	644	65.12
0.17-0.18	34	3.44	678	68.55
0.18-0.19	47	4.75	725	73.31
0.19-0.2	29	2.93	754	76.24
0.2-0.21	26	2.63	780	78.87
0.21-0.22	22	2.22	802	81.09
0.22-0.23	28	2.83	830	83.92
0.23-0.24	20	2.02	850	85.95
0.24-0.25	13	1.31	863	87.26
0.25-0.26	16	1.62	879	88.88
0.26-0.27	17	1.72	896	90.6
0.27-0.28	13	1.31	909	91.91
0.28-0.29	9	0.91	918	92.82
0.29-0.3	8	0.81	926	93.63
0.3-0.31	6	0.61	932	94.24
0.31-0.32	6	0.61	938	94.84
0.32-0.33	2	0.2	940	95.05
0.33-0.34	2	0.2	942	95.25
0.34-0.35	3	0.3	945	95.55
0.35-0.36	3	0.3	948	95.85
0.36-0.37	5	0.51	953	96.36
0.37-0.38	1	0.1	954	96.46
0.38-0.39	4	0.4	958	96.87
0.39-0.4	4	0.4	962	97.27
0.4-0.41	7	0.71	969	97.98
0.41-0.42	0	0	969	97.98
0.42-0.43	2	0.2	971	98.18
0.43-0.44	1	0.1	972	98.28
0.44-0.45	4	0.4	976	98.69
0.45-0.46	3	0.3	979	98.99
0.46-0.47	0	0	979	98.99
0.47-0.48	1	0.1	980	99.09
0.48-0.49	1	0.1	981	99.19
0.49-0.5	3	0.3	984	99.49
0.5-0.51	0	0	984	99.49
0.51-0.52	0	0	984	99.49
0.52-0.53	0	0	984	99.49
0.53-0.54	0	0	984	99.49
0.54-0.55	0	0	984	99.49
0.55-0.56	0	0	984	99.49

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.56-0.57	0	0	984	99.49
0.57-0.58	1	0.1	985	99.6
0.58-0.59	0	0	985	99.6
0.59-0.6	0	0	985	99.6
0.6-0.61	0	0	985	99.6
0.61-0.62	0	0	985	99.6
0.62-0.63	0	0	985	99.6
0.63-0.64	0	0	985	99.6
0.64-0.65	1	0.1	986	99.7
0.65-0.66	0	0	986	99.7
0.66-0.67	0	0	986	99.7
0.67-0.68	0	0	986	99.7
0.68-0.69	0	0	986	99.7
0.69-0.7	0	0	986	99.7
0.7-0.71	1	0.1	987	99.8
0.71-0.72	0	0	987	99.8
0.72-0.73	0	0	987	99.8
0.73-0.74	1	0.1	988	99.9
0.74-0.75	0	0	988	99.9
0.75-0.76	0	0	988	99.9
0.76-0.77	0	0	988	99.9
0.77-0.78	0	0	988	99.9
0.78-0.79	0	0	988	99.9
0.79-0.8	0	0	988	99.9
0.8-0.81	0	0	988	99.9
0.81-0.82	0	0	988	99.9
0.82-0.83	0	0	988	99.9
0.83-0.84	0	0	988	99.9
0.84-0.85	0	0	988	99.9
0.85-0.86	0	0	988	99.9
0.86-0.87	0	0	988	99.9
0.87-0.88	0	0	988	99.9
0.88-0.89	0	0	988	99.9
0.89-0.9	0	0	988	99.9
0.9-0.91	0	0	988	99.9
0.91-0.92	0	0	988	99.9
0.92-0.93	0	0	988	99.9
0.93-0.94	0	0	988	99.9
0.94-0.95	0	0	988	99.9
0.95-0.96	0	0	988	99.9
0.96-0.97	0	0	988	99.9
0.97-0.98	0	0	988	99.9
0.98-0.99	0	0	988	99.9
0.99-1	1	0.1	989	100

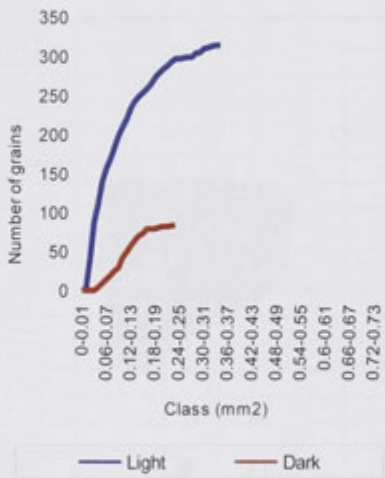


Fig 1-163. Cumulative amount of grains.

AME 2

Data sheet

Fig 1-164.

Fig 1-165.

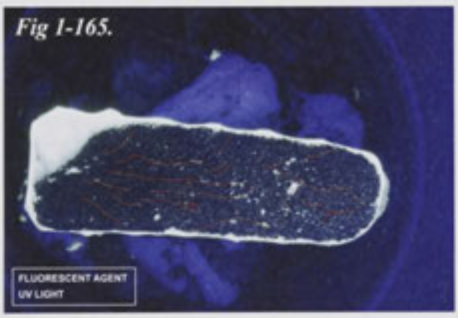


Fig 1-166.

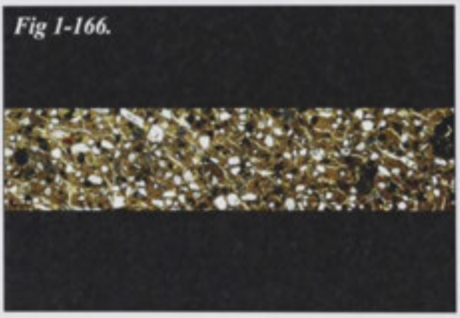


Table 1-58. Dark grains.

Dark grains

Number of Objects	Area Fraction	Area (mm²)	Measured Area (mm²)
1079	0.075	4.27	57.26

Feature	Mean	SD	Minimum	Maximum
Area (mm²)	0.004	0.003	0.0003	0.03
Equivalent Diameter (mm)	0.07	0.03	0.02	0.19
Circularity	0.862	0.095	0.408	1
Max Feret (mm²)	0.09	0.03	0.02	0.28

Class (mm²)	Amount	Amount (%)	Cumulative	Cumulative (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	6	0.56	6	0.56
0.03-0.04	39	3.61	45	4.17
0.04-0.05	102	9.45	147	13.62
0.05-0.06	129	11.96	276	25.58
0.06-0.07	112	10.38	388	35.96
0.07-0.08	134	12.42	522	48.38
0.08-0.09	142	13.16	664	61.54
0.09-0.1	140	12.97	804	74.51
0.1-0.11	81	7.51	885	82.02
0.11-0.12	66	6.12	951	88.14
0.12-0.13	31	2.87	982	91.01

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.13-0.14	30	2.78	1012	93.79
0.14-0.15	12	1.11	1024	94.9
0.15-0.16	13	1.2	1037	96.11
0.16-0.17	9	0.83	1046	96.94
0.17-0.18	10	0.93	1056	97.87
0.18-0.19	5	0.46	1061	98.33
0.19-0.2	5	0.46	1066	98.8
0.2-0.21	4	0.37	1070	99.17
0.21-0.22	3	0.28	1073	99.44
0.22-0.23	1	0.09	1074	99.54
0.23-0.24	0	0	1074	99.54
0.24-0.25	1	0.09	1075	99.63
0.25-0.26	1	0.09	1076	99.72
0.26-0.27	1	0.09	1077	99.81
0.27-0.28	1	0.09	1078	99.91
0.28-0.29	1	0.09	1079	100

Light grains

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
1619	0.185	10.59	57.26

Feature	Mean	SD	Minimum	Maximum
Area (mm^2)	0.01	0.01	0.0001	0.06
Equivalent Diameter (mm)	0.08	0.03	0.01	0.28
Circularity	0.833	0.116	0.238	1
Max Feret (mm^2)	0.11	0.05	0.02	0.4

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0-0.01	0	0	0	0
0.01-0.02	1	0.06	1	0.06
0.02-0.03	4	0.25	5	0.31
0.03-0.04	22	1.36	27	1.67
0.04-0.05	62	3.83	89	5.5
0.05-0.06	87	5.37	176	10.87
0.06-0.07	125	7.72	301	18.59
0.07-0.08	130	8.03	431	26.62
0.08-0.09	167	10.32	598	36.94
0.09-0.1	162	10.01	760	46.94
0.1-0.11	142	8.77	902	55.71
0.11-0.12	135	8.34	1037	64.05
0.12-0.13	116	7.16	1153	71.22
0.13-0.14	115	7.1	1268	78.32
0.14-0.15	86	5.31	1354	83.63
0.15-0.16	45	2.78	1399	86.41
0.16-0.17	46	2.84	1445	89.25
0.17-0.18	38	2.35	1483	91.6

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.18-0.19	22	1.36	1505	92.96
0.19-0.2	32	1.98	1537	94.94
0.2-0.21	16	0.99	1553	95.92
0.21-0.22	10	0.62	1563	96.54
0.22-0.23	9	0.56	1572	97.1
0.23-0.24	13	0.8	1585	97.9
0.24-0.25	13	0.8	1598	98.7
0.25-0.26	5	0.31	1603	99.01
0.26-0.27	1	0.06	1604	99.07
0.27-0.28	0	0	1604	99.07
0.28-0.29	5	0.31	1609	99.38
0.29-0.3	2	0.12	1611	99.51
0.3-0.31	2	0.12	1613	99.63
0.31-0.32	1	0.06	1614	99.69
0.32-0.33	2	0.12	1616	99.81
0.33-0.34	0	0	1616	99.81
0.37-0.38	1	0.06	1617	99.88
0.38-0.39	1	0.06	1618	99.94
0.39-0.4	1	0.06	1619	100

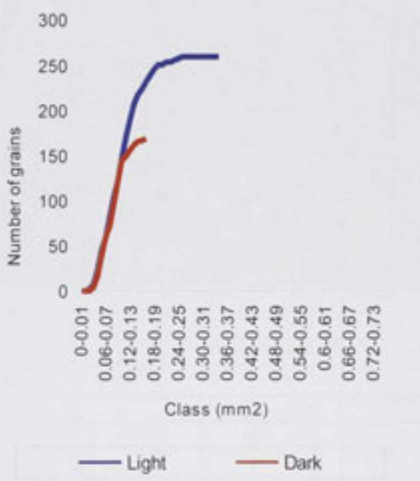


Fig 1-167. Cumulative amount of grains.

AME 11
Data sheet

Fig 1-168.

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1:4

ø22 cm

Fig 1-169.

Fig 1-170.

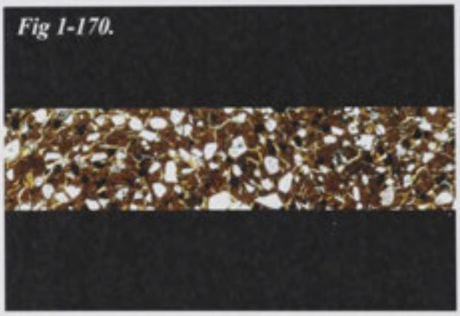

Table 1-59. Temper data.

Dark grains

Number of Objects	Area Fraction	Area (mm²)	Measured Area (mm²)
659	0.067	3.86	57.26

Feature	Mean	SD	Minimum	Maximum
Area (mm²)	0.01	0.01	0.0005	0.07
Equivalent Diameter (mm)	0.08	0.04	0.02	0.29
Circularity	0.867	0.086	0.271	1
Max Feret (mm²)	0.1	0.05	0.03	0.4

Class (mm²)	Amount	Amount (%)	Cumulative	Cumulative (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	1	0.15	1	0.15
0.03-0.04	18	2.73	19	2.88
0.04-0.05	57	8.65	76	11.53
0.05-0.06	50	7.59	126	19.12
0.06-0.07	71	10.77	197	29.89
0.07-0.08	60	9.1	257	39
0.08-0.09	58	8.8	315	47.8
0.09-0.1	57	8.65	372	56.45
0.1-0.11	48	7.28	420	63.73
0.11-0.12	56	8.5	476	72.23
0.12-0.13	37	5.61	513	77.85

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.13-0.14	41	6.22	554	84.07
0.14-0.15	35	5.31	589	89.38
0.15-0.16	16	2.43	605	91.81
0.16-0.17	15	2.28	620	94.08
0.17-0.18	11	1.67	631	95.75
0.18-0.19	8	1.21	639	96.97
0.19-0.2	3	0.46	642	97.42
0.2-0.21	3	0.46	645	97.88
0.21-0.22	3	0.46	648	98.33
0.22-0.23	1	0.15	649	98.48
0.23-0.24	0	0	649	98.48
0.24-0.25	1	0.15	650	98.63
0.25-0.26	0	0	650	98.63
0.26-0.27	3	0.46	653	99.09
0.27-0.28	0	0	653	99.09
0.28-0.29	2	0.3	655	99.39
0.29-0.3	1	0.15	656	99.54
0.3-0.31	1	0.15	657	99.7
0.31-0.32	0	0	657	99.7
0.32-0.33	0	0	657	99.7
0.33-0.34	0	0	657	99.7
0.34-0.35	0	0	657	99.7
0.35-0.36	0	0	657	99.7
0.36-0.37	0	0	657	99.7
0.37-0.38	1	0.15	658	99.85
0.38-0.39	0	0	658	99.85
0.39-0.4	0	0	658	99.85
0.4-0.41	1	0.15	659	100

Light grains

Number of Objects	Area Fraction	Area (mm²)	Measured Area (mm²)
1102	0.207	11.87	57.26

Feature	Mean	SD	Minimum	Maximum
Area (mm²)	0.01	0.01	0.00003	0.09
Equivalent Diameter (mm)	0.1	0.05	0.01	0.34
Circularity	0.822	0.117	0.284	1
Max Feret (mm²)	0.14	0.08	0.01	0.56

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0-0.01	0	0	0	0
0.01-0.02	2	0.18	2	0.18
0.02-0.03	3	0.27	5	0.45
0.03-0.04	29	2.63	34	3.09
0.04-0.05	59	5.35	93	8.44

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.05-0.06	58	5.26	151	13.7
0.06-0.07	57	5.17	208	18.87
0.07-0.08	56	5.08	264	23.96
0.08-0.09	65	5.9	329	29.85
0.09-0.1	61	5.54	390	35.39
0.1-0.11	57	5.17	447	40.56
0.11-0.12	67	6.08	514	46.64
0.12-0.13	62	5.63	576	52.27
0.13-0.14	63	5.72	639	57.99
0.14-0.15	57	5.17	696	63.16
0.15-0.16	51	4.63	747	67.79
0.16-0.17	49	4.45	796	72.23
0.17-0.18	41	3.72	837	75.95
0.18-0.19	31	2.81	868	78.77
0.19-0.2	35	3.18	903	81.94
0.2-0.21	28	2.54	931	84.48
0.21-0.22	17	1.54	948	86.03
0.22-0.23	23	2.09	971	88.11
0.23-0.24	23	2.09	994	90.2
0.24-0.25	20	1.81	1014	92.01
0.25-0.26	14	1.27	1028	93.28
0.26-0.27	10	0.91	1038	94.19
0.27-0.28	8	0.73	1046	94.92
0.28-0.29	10	0.91	1056	95.83
0.29-0.3	6	0.54	1062	96.37
0.3-0.31	5	0.45	1067	96.82
0.31-0.32	4	0.36	1071	97.19
0.32-0.33	3	0.27	1074	97.46
0.33-0.34	2	0.18	1076	97.64
0.34-0.35	2	0.18	1078	97.82
0.35-0.36	5	0.45	1083	98.28
0.36-0.37	0	0	1083	98.28
0.37-0.38	2	0.18	1085	98.46
0.38-0.39	2	0.18	1087	98.64
0.39-0.4	3	0.27	1090	98.91
0.4-0.41	0	0	1090	98.91
0.41-0.42	2	0.18	1092	99.09
0.42-0.43	3	0.27	1095	99.36
0.43-0.44	0	0	1095	99.36
0.44-0.45	0	0	1095	99.36
0.45-0.46	4	0.36	1099	99.73
0.46-0.47	0	0	1099	99.73
0.47-0.48	0	0	1099	99.73
0.48-0.49	1	0.09	1100	99.82
0.49-0.5	0	0	1100	99.82
0.5-0.51	1	0.09	1101	99.91
0.51-0.52	0	0	1101	99.91
0.52-0.53	0	0	1101	99.91

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.53-0.54	0	0	1101	99.91
0.54-0.55	0	0	1101	99.91
0.55-0.56	1	0.09	1102	100

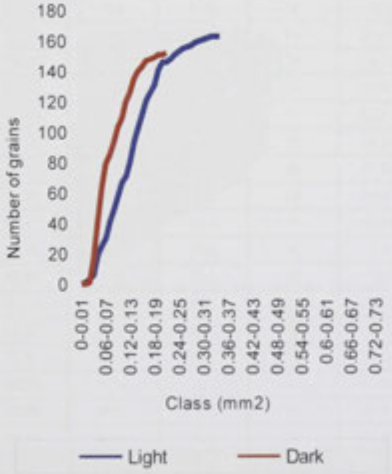

Fig 1-171. Cumulative amount of grains.

AME 15

Data sheet

Fig 1-172.

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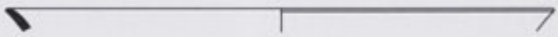

ø38 cm

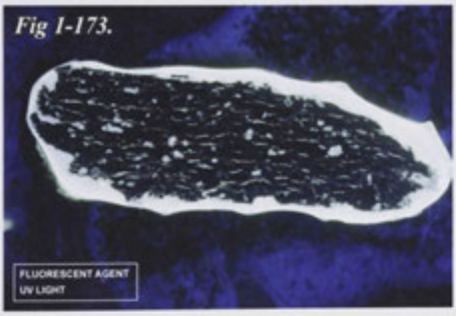

Fig 1-173.

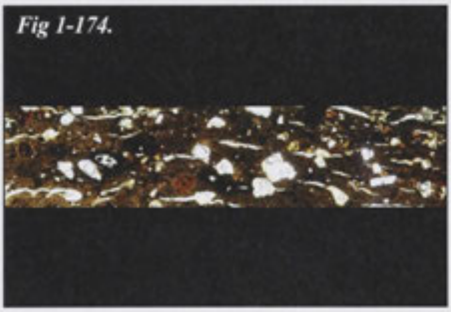

Fig 1-174.

Table 1-60. Temper data.

Dark grains

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
33	0.013	0.1	7.9

Feature	Mean	SD	Minimum	Maximum
Area (mm^2)	0.003	0.002	0.0008	0.01
Equivalent Diameter (mm)	0.06	0.02	0.03	0.12
Circularity	0.874	0.071	0.645	0.982
Max Feret (mm^2)	0.07	0.03	0.04	0.14

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	0	0	0	0
0.03-0.04	0	0	0	0
0.04-0.05	9	27.27	9	27.27
0.05-0.06	6	18.18	15	45.45
0.06-0.07	4	12.12	19	57.58
0.07-0.08	2	6.06	21	63.64
0.08-0.09	1	3.03	22	66.67
0.09-0.1	5	15.15	27	81.82
0.1-0.11	1	3.03	28	84.85
0.11-0.12	0	0	28	84.85

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.12-0.13	2	6.06	30	90.91
0.13-0.14	3	9.09	33	100

Light grains

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
95	0.104	0.82	7.9

Feature	Mean	SD	Minimum	Maximum
Area (mm^2)	0.01	0.01	0.0003	0.07
Equivalent Diameter (mm)	0.08	0.06	0.02	0.3
Circularity	0.781	0.159	0.21	0.971
Max Feret (mm^2)	0.11	0.09	0.02	0.37

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	4	4.21	4	4.21
0.03-0.04	12	12.63	16	16.84
0.04-0.05	11	11.58	27	28.42
0.05-0.06	12	12.63	39	41.05
0.06-0.07	9	9.47	48	50.53
0.07-0.08	4	4.21	52	54.74
0.08-0.09	4	4.21	56	58.95
0.09-0.1	2	2.11	58	61.05
0.1-0.11	1	1.05	59	62.11
0.11-0.12	4	4.21	63	66.32
0.12-0.13	4	4.21	67	70.53
0.13-0.14	2	2.11	69	72.63
0.14-0.15	2	2.11	71	74.74
0.15-0.16	1	1.05	72	75.79
0.16-0.17	2	2.11	74	77.89
0.17-0.18	2	2.11	76	80
0.18-0.19	1	1.05	77	81.05
0.19-0.2	1	1.05	78	82.11
0.2-0.21	2	2.11	80	84.21
0.21-0.22	2	2.11	82	86.32
0.22-0.23	0	0	82	86.32
0.23-0.24	1	1.05	83	87.37
0.24-0.25	1	1.05	84	88.42
0.25-0.26	1	1.05	85	89.47
0.26-0.27	0	0	85	89.47
0.27-0.28	1	1.05	86	90.53
0.28-0.29	3	3.16	89	93.68
0.29-0.3	0	0	89	93.68
0.3-0.31	1	1.05	90	94.74

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.31-0.32	0	0	90	94.74
0.32-0.33	1	1.05	91	95.79
0.33-0.34	0	0	91	95.79
0.34-0.35	0	0	91	95.79
0.35-0.36	0	0	91	95.79
0.36-0.37	2	2.11	93	97.89
0.37-0.38	2	2.11	95	100

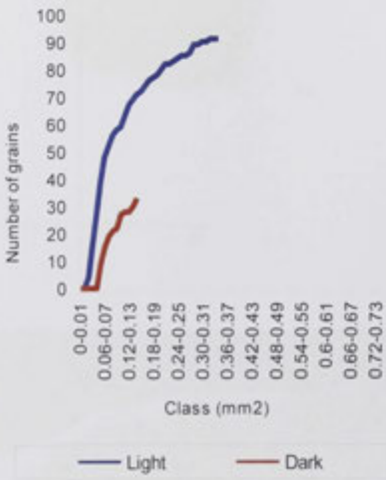

Fig 1-175. Cumulative amount of grains.

AME 20

Data sheet

Fig 1-176.

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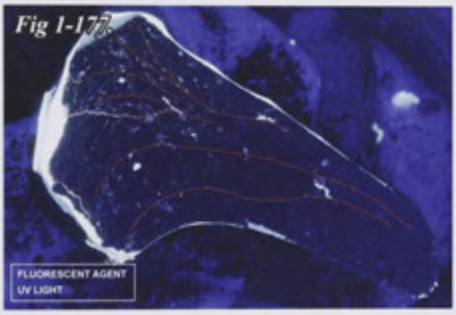


Fig 1-177.

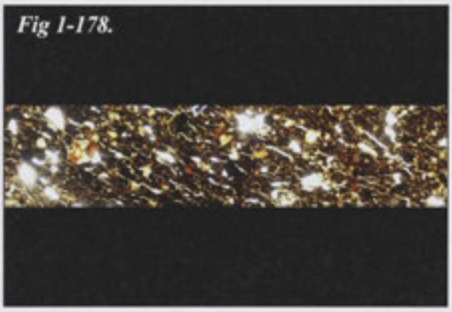


Fig 1-178.

Table 1-61. Temper data

Dark grains

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
89	0.033	0.26	7.88

Feature	Mean	SD	Minimum	Maximum
Area (mm^2)	0.003	0.004	0.0005	0.03
Equivalent Diameter (mm)	0.05	0.03	0.03	0.18
Circularity	0.866	0.076	0.534	0.965
Max Feret (mm^2)	0.07	0.04	0.03	0.23

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	2	2.25	2	2.25
0.03-0.04	8	8.99	10	11.24
0.04-0.05	23	25.84	33	37.08
0.05-0.06	17	19.1	50	56.18
0.06-0.07	14	15.73	64	71.91
0.07-0.08	5	5.62	69	77.53
0.08-0.09	3	3.37	72	80.9
0.09-0.1	4	4.49	76	85.39
0.1-0.11	3	3.37	79	88.76
0.11-0.12	2	2.25	81	91.01
0.12-0.13	1	1.12	82	92.13
0.13-0.14	2	2.25	84	94.38
0.14-0.15	2	2.25	86	96.63
0.15-0.16	1	1.12	87	97.75
0.16-0.17	0	0	87	97.75
0.17-0.18	1	1.12	88	98.88
0.18-0.13	0	0	88	98.88

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.23-0.24	1	1.12	89	100

Light grains

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
169	0.117	0.92	7.88

Feature	Mean	SD	Minimum	Maximum
Area (mm^2)	0.01	0.01	0.00006	0.1
Equivalent Diameter (mm)	0.07	0.05	0.01	0.35
Circularity	0.795	0.114	0.406	0.961
Max Feret (mm^2)	0.09	0.07	0.02	0.44

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0-0.01	0	0	0	0
0.01-0.02	5	2.96	5	2.96
0.02-0.03	7	4.14	12	7.1
0.03-0.04	21	12.43	33	19.53
0.04-0.05	23	13.61	56	33.14
0.05-0.06	16	9.47	72	42.6
0.06-0.07	14	8.28	86	50.89
0.07-0.08	14	8.28	100	59.17
0.08-0.09	7	4.14	107	63.31
0.09-0.1	9	5.33	116	68.64
0.1-0.11	7	4.14	123	72.78
0.11-0.12	8	4.73	131	77.51
0.12-0.13	4	2.37	135	79.88
0.13-0.14	5	2.96	140	82.84
0.14-0.15	5	2.96	145	85.8
0.15-0.16	4	2.37	149	88.17
0.16-0.17	0	0	149	88.17
0.17-0.18	4	2.37	153	90.53
0.18-0.19	3	1.78	156	92.31
0.19-0.2	2	1.18	158	93.49
0.2-0.21	1	0.59	159	94.08
0.21-0.22	0	0	159	94.08
0.22-0.23	1	0.59	160	94.67
0.23-0.24	2	1.18	162	95.86
0.24-0.27	0	0	162	95.86
0.27-0.28	1	0.59	163	96.45
0.28-0.29	1	0.59	164	97.04
0.29-0.3	1	0.59	165	97.63
0.3-0.31	1	0.59	166	98.22
0.31-0.32	0	0	166	98.22
0.32-0.33	1	0.59	167	98.82
0.33-0.39	0	0	167	98.82
0.39-0.4	1	0.59	168	99.41
0.4-0.44	0	0	168	99.41
0.44-0.45	1	0.59	169	100

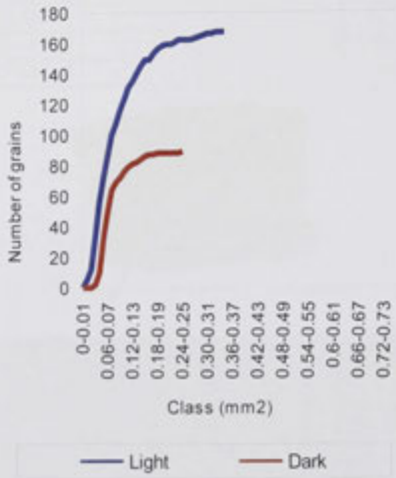


Fig 1-179. Cumulative amount of grains.

AME 23

Data sheet

Fig 1-180.

SCALE 1:1

1:1

1:4

ø32 cm

Fig 1-183.

Fig 1-184.

Table 1-62. Temper data.

Dark grains

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
93	0.023	0.18	7.9

Feature	Mean	SD	Minimum	Maximum
Area (mm^2)	0.002	0.003	0.0001	0.01
Equivalent Diameter (mm)	0.04	0.03	0.01	0.13
Circularity	0.848	0.089	0.556	0.977
Max Feret (mm^2)	0.05	0.04	0.02	0.19

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0-0.01	0	0	0	0
0.01-0.02	4	4.3	4	4.3
0.02-0.03	22	23.66	26	27.96
0.03-0.04	20	21.51	46	49.46
0.04-0.05	14	15.05	60	64.52
0.05-0.06	10	10.75	70	75.27
0.06-0.07	4	4.3	74	79.57
0.07-0.08	1	1.08	75	80.65
0.08-0.09	3	3.23	78	83.87
0.09-0.1	2	2.15	80	86.02
0.1-0.11	4	4.3	84	90.32
0.11-0.12	2	2.15	86	92.47

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.12-0.13	2	2.15	88	94.62
0.13-0.14	1	1.08	89	95.7
0.14-0.15	1	1.08	90	96.77
0.15-0.16	1	1.08	91	97.85
0.16-0.17	0	0	91	97.85
0.17-0.18	0	0	91	97.85
0.18-0.19	1	1.08	92	98.92
0.19-0.2	1	1.08	93	100

Light grains

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
182	0.234	1.85	7.9

Feature	Mean	SD	Minimum	Maximum
Area (mm^2)	0.01	0.01	0.0002	0.09
Equivalent Diameter (mm)	0.09	0.07	0.01	0.34
Circularity	0.8	0.136	0.119	0.975
Max Feret (mm^2)	0.12	0.09	0.02	0.54

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	13	7.14	13	7.14
0.03-0.04	26	14.29	39	21.43
0.04-0.05	4	2.2	43	23.63
0.05-0.06	14	7.69	57	31.32
0.06-0.07	11	6.04	68	37.36
0.07-0.08	8	4.4	76	41.76
0.08-0.09	10	5.49	86	47.25
0.09-0.1	4	2.2	90	49.45
0.1-0.11	5	2.75	95	52.2
0.11-0.12	6	3.3	101	55.49
0.12-0.13	8	4.4	109	59.89
0.13-0.14	4	2.2	113	62.09
0.14-0.15	5	2.75	118	64.84
0.15-0.16	8	4.4	126	69.23
0.16-0.17	9	4.95	135	74.18
0.17-0.18	4	2.2	139	76.37
0.18-0.19	3	1.65	142	78.02
0.19-0.2	6	3.3	148	81.32
0.2-0.21	2	1.1	150	82.42
0.21-0.22	7	3.85	157	86.26
0.22-0.23	1	0.55	158	86.81
0.23-0.24	1	0.55	159	87.36
0.24-0.25	4	2.2	163	89.56
0.25-0.26	2	1.1	165	90.66
0.26-0.27	4	2.2	169	92.86
0.27-0.28	6	3.3	175	96.15
0.28-0.29	1	0.55	176	96.7
0.29-0.3	1	0.55	177	97.25
0.3-0.31	0	0	177	97.25
0.31-0.32	0	0	177	97.25
0.32-0.33	2	1.1	179	98.35
0.33-0.34	0	0	179	98.35
0.34-0.35	0	0	179	98.35
0.35-0.36	1	0.55	180	98.9

0.42-0.43	1	0.55	181	99.45

0.54-0.55	1	0.55	182	100

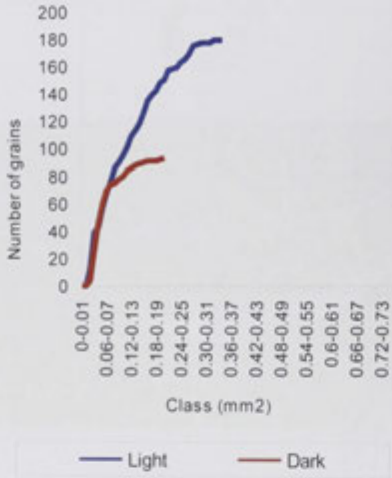


Fig 1-185. Cumulative amount of grains.

AME 25

Data sheet

Fig 1-186.

SCALE 1:1

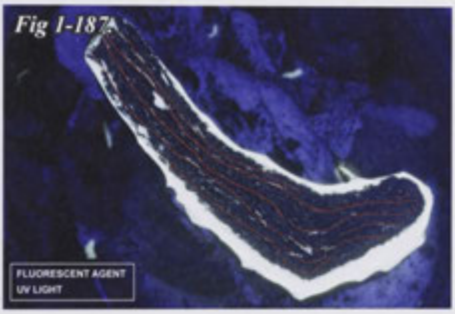


Fig 1-187.

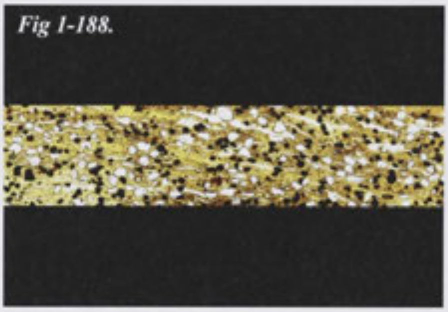


Fig 1-188.

Table 1-63. Temper data.

Dark grains

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
315	0.128	1.01	7.9

Feature	Mean	SD	Minimum	Maximum
Area (mm^2)	0.003	0.002	0.00003	0.02
Equivalent Diameter (mm)	0.06	0.03	0.01	0.14
Circularity	0.832	0.108	0.26	0.968
Max Feret (mm^2)	0.08	0.03	0.01	0.24

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0-0.01	0	0	0	0
0.01-0.02	2	0.63	2	0.63
0.02-0.03	19	6.03	21	6.67
0.03-0.04	36	11.43	57	18.1
0.04-0.05	33	10.48	90	28.57
0.05-0.06	14	4.44	104	33.02
0.06-0.07	32	10.16	136	43.17
0.07-0.08	31	9.84	167	53.02
0.08-0.09	38	12.06	205	65.08
0.09-0.1	40	12.7	245	77.78
0.1-0.11	30	9.52	275	87.3
0.11-0.12	19	6.03	294	93.33
0.12-0.13	9	2.86	303	96.19
0.13-0.14	4	1.27	307	97.46
0.14-0.15	1	0.32	308	97.78
0.15-0.16	1	0.32	309	98.1
0.16-0.17	2	0.63	311	98.73
0.17-0.18	1	0.32	312	99.05
0.18-0.19	1	0.32	313	99.37

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.19-0.2	1	0.32	314	99.68
0.2-0.21	0	0	314	99.68
0.21-0.22	0	0	314	99.68
0.22-0.23	0	0	314	99.68
0.23-0.24	0	0	314	99.68
0.24-0.25	1	0.32	315	100

Light grains

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
193	0.139	1.1	7.9

Feature	Mean	SD	Minimum	Maximum
Area (mm^2)	0.01	0.005	0.00009	0.03
Equivalent Diameter (mm)	0.08	0.04	0.01	0.2
Circularity	0.539	0.207	0.126	0.944
Max Feret (mm^2)	0.11	0.06	0.02	0.34

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0-0.01	0	0	0	0
0.01-0.02	1	0.52	1	0.52
0.02-0.03	4	2.07	5	2.59
0.03-0.04	11	5.7	16	8.29
0.04-0.05	15	7.77	31	16.06
0.05-0.06	7	3.63	38	19.69
0.06-0.07	11	5.7	49	25.39
0.07-0.08	8	4.15	57	29.53
0.08-0.09	16	8.29	73	37.82
0.09-0.1	5	2.59	78	40.41
0.1-0.11	13	6.74	91	47.15
0.11-0.12	14	7.25	105	54.4
0.12-0.13	15	7.77	120	62.18
0.13-0.14	9	4.66	129	66.84
0.14-0.15	13	6.74	142	73.58
0.15-0.16	11	5.7	153	79.27
0.16-0.17	9	4.66	162	83.94
0.17-0.18	11	5.7	173	89.64
0.18-0.19	6	3.11	179	92.75
0.19-0.2	3	1.55	182	94.3
0.2-0.21	4	2.07	186	96.37
0.21-0.22	1	0.52	187	96.89
0.22-0.23	1	0.52	188	97.41
0.23-0.24	1	0.52	189	97.93
0.24-0.25	0	0	189	97.93
0.25-0.26	0	0	189	97.93
0.26-0.27	1	0.52	190	98.45
0.27-0.28	1	0.52	191	98.96
...				
0.33-0.34	1	0.52	192	99.48
0.34-0.35	1	0.52	193	100

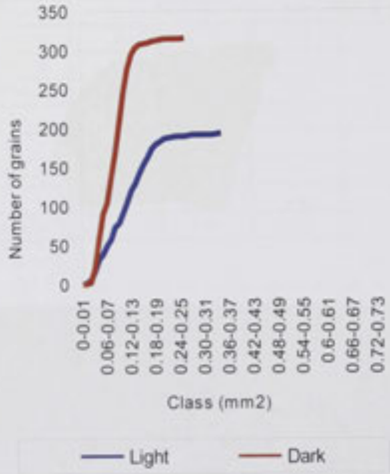


Fig 1-189. Cumulative amount of grains.

AME 26

Data sheet

Fig 1-190.

Fig.1-191.

Fig 1-192.

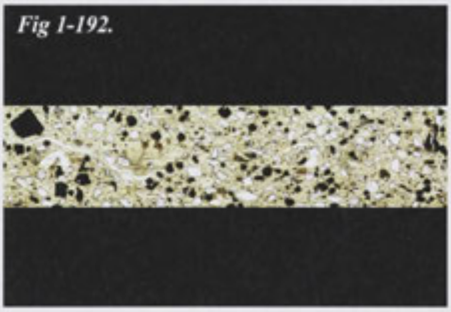


Table 1-64. Temper data.

Dark grains

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
276	0.114	0.9	7.9

Feature	Mean	SD	Minimum	Maximum
Area (mm^2)	0.003	0.01	0.00006	0.11
Equivalent Diameter (mm)	0.05	0.04	0.01	0.37
Circularity	0.814	0.106	0.447	0.989
Max Feret (mm^2)	0.07	0.05	0.01	0.48

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0-0.01	0	0	0	0
0.01-0.02	13	4.71	13	4.71
0.02-0.03	51	18.48	64	23.19
0.03-0.04	33	11.96	97	35.14
0.04-0.05	28	10.14	125	45.29
0.05-0.06	22	7.97	147	53.26
0.06-0.07	20	7.25	167	60.51
0.07-0.08	15	5.43	182	65.94
0.08-0.09	16	5.8	198	71.74
0.09-0.1	21	7.61	219	79.35
0.1-0.11	15	5.43	234	84.78
0.11-0.12	13	4.71	247	89.49
0.12-0.13	5	1.81	252	91.3

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.13-0.14	6	2.17	258	93.48
0.14-0.15	7	2.54	265	96.01
0.15-0.16	2	0.72	267	96.74
0.16-0.17	4	1.45	271	98.19
0.17-0.18	1	0.36	272	98.55
0.18-0.19	1	0.36	273	98.91
0.19-0.2	0	0	273	98.91
0.2-0.21	0	0	273	98.91
0.21-0.22	0	0	273	98.91
0.22-0.23	0	0	273	98.91
0.23-0.24	1	0.36	274	99.28
0.24-0.25	1	0.36	275	99.64
...				
0.47-0.48	1	0.36	276	100

Light grains

Number of Objects	Area Fraction	Area (mm^2)	Measured Area (mm^2)
206	0.146	1.15	7.9

Feature	Mean	SD	Minimum	Maximum
Area (mm^2)	0.01	0.005	0.00001	0.03
Equivalent Diameter (mm)	0.08	0.04	0.004	0.18
Circularity	0.736	0.179	0.155	0.967
Max Feret (mm^2)	0.11	0.05	0.02	0.31

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0-0.01	0	0	0	0
0.01-0.02	2	0.97	2	0.97
0.02-0.03	8	3.88	10	4.85
0.03-0.04	13	6.31	23	11.17
0.04-0.05	15	7.28	38	18.45
0.05-0.06	10	4.85	48	23.3
0.06-0.07	11	5.34	59	28.64
0.07-0.08	7	3.4	66	32.04
0.08-0.09	20	9.71	86	41.75
0.09-0.1	13	6.31	99	48.06
0.1-0.11	13	6.31	112	54.37
0.11-0.12	13	6.31	125	60.68
0.12-0.13	13	6.31	138	66.99
0.13-0.14	16	7.77	154	74.76
0.14-0.15	10	4.85	164	79.61
0.15-0.16	5	2.43	169	82.04
0.16-0.17	7	3.4	176	85.44
0.17-0.18	6	2.91	182	88.35
0.18-0.19	10	4.85	192	93.2
0.19-0.2	5	2.43	197	95.63
0.2-0.21	4	1.94	201	97.57
0.21-0.22	1	0.49	202	98.06
0.22-0.23	1	0.49	203	98.54
0.23-0.24	0	0	203	98.54
0.24-0.25	1	0.49	204	99.03
0.25-0.26	0	0	204	99.03
0.26-0.27	0	0	204	99.03
0.27-0.28	1	0.49	205	99.51
0.28-0.29	0	0	205	99.51
0.29-0.3	0	0	205	99.51
0.3-0.31	1	0.49	206	100

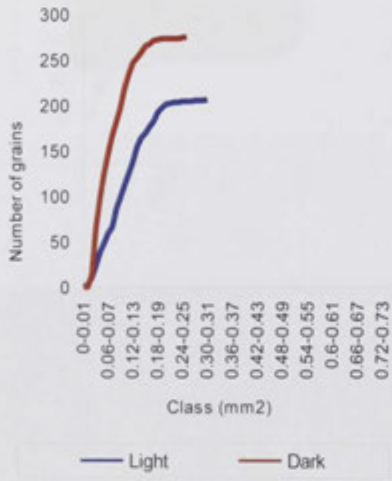
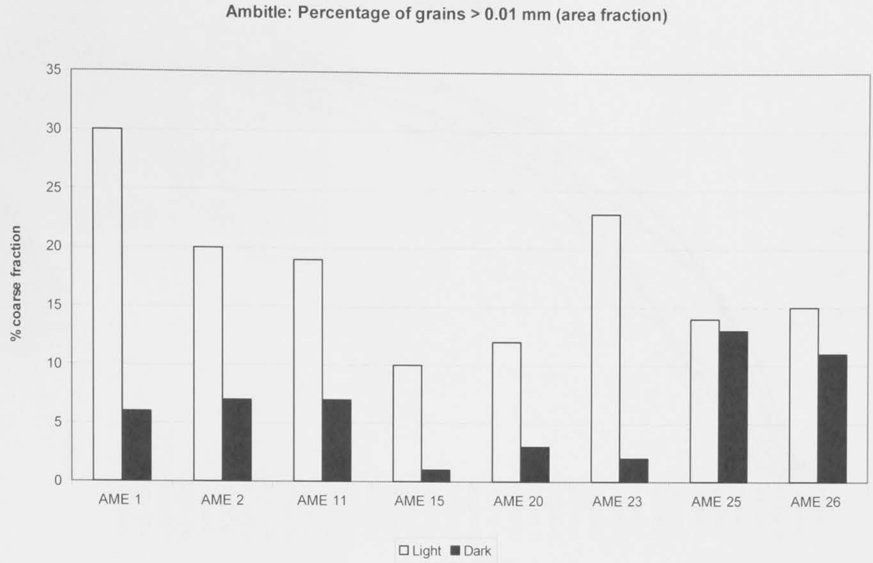
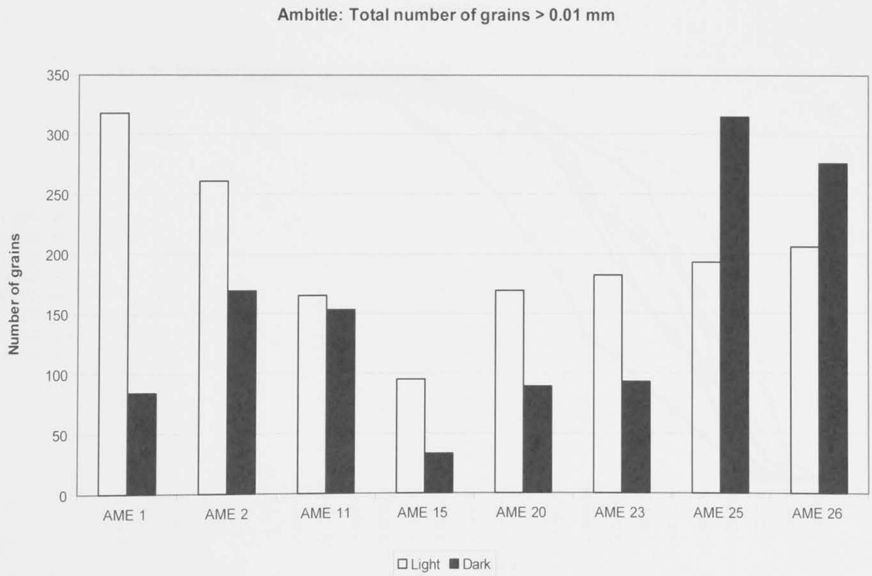
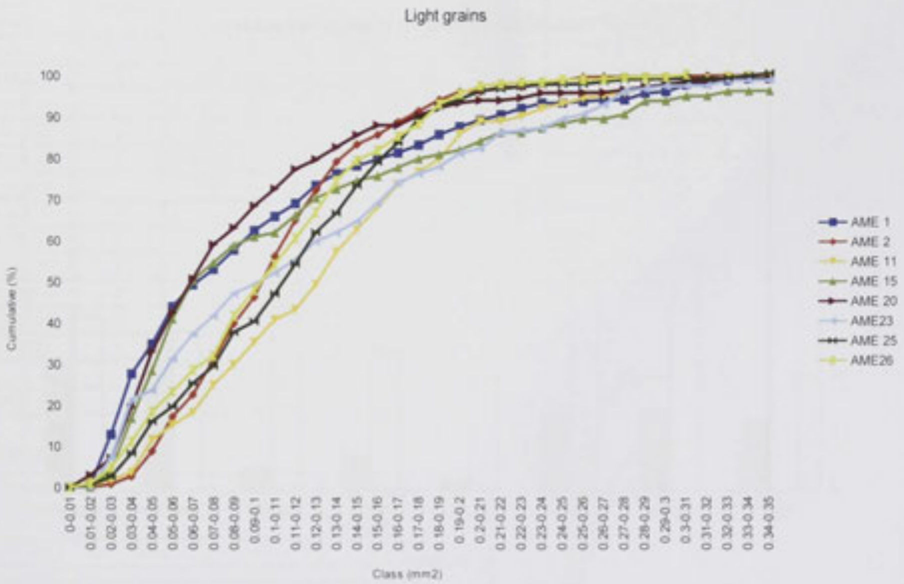


Fig 1-193. Cumulative amount of grains.


Ambitle: Percentage of grains > 0.01 mm (area fraction)
% coarse fraction
35
30
25
20
15
10
5
0
AME 1
AME 2
AME 11
AME 15
AME 20
AME 23
AME 25
AME 26
Light
Dark


Ambitle: Total number of grains > 0.01 mm
Number of grains
350
300
250
200
150
100
50
0
AME 1
AME 2
AME 11
AME 15
AME 20
AME 23
AME 25
AME 26
Light
Dark


Light grains
Cumulative (%)
Class (mm2)
AME 1
AME 2
AME 11
AME 15
AME 20
AME23
AME 25
AME26

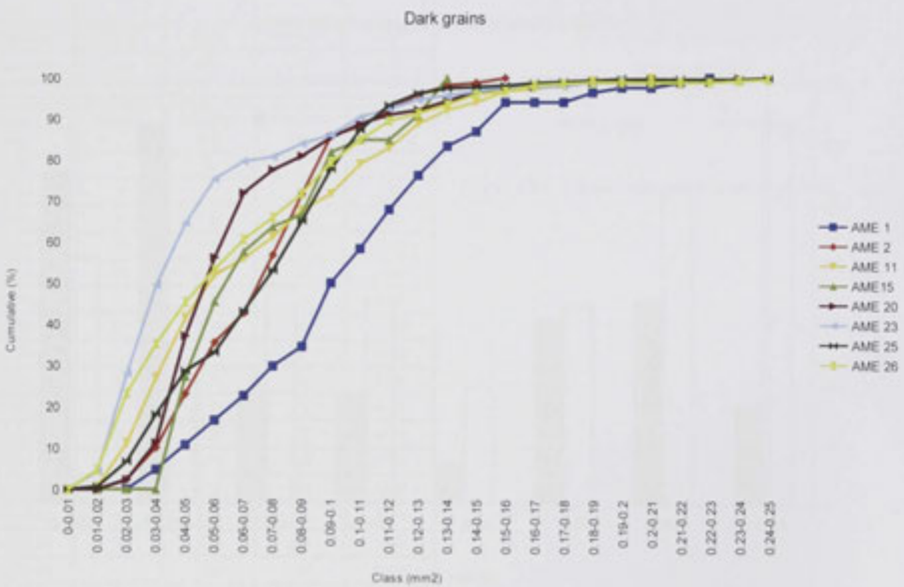

Dark grains
Cumulative (%)
Class (mm2)
AME 1
AME 2
AME 11
AME15
AME 20
AME 23
AME 25
AME 26

Table 1-65. Result of pore line analysis..

Lab. no.	Maufacturing technique
AME 1	Paddle and anvil
AME 2	Possibly paddle and anvil
AME 11	Paddle and anvil
AME 15	Paddle and anvil
AME 20	Paddle and anvil
AME 23	Paddle and anvil
AME 25	Paddle and anvil
AME 26	Paddle and anvil

Table 1-66. Thermal test results.

	Temperature (°C)	20	100	200	300	400	500	600	700	800	900	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500
AME 1	Hue	1		1	2	2	2	2	2	2	2	2	2	2	2	2	2					
	Value	6		5	4	4	5	5	6	6	5	5	5	5	4	3	3					
	Chroma	6		6	2	3	6	6	8	6	8	8	6	6	3	2	1					
	Phase									**F**									S			
AME 3	Hue	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2					
	Value	4		4	4	4	5	6	5	4	5	6	4	4	4	4	3					
	Chroma	6		6	4	4	4	6	6	6	8	6	4	4	3	2	2					
	Phase									**F**								S				
AME 8	Hue	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2		
	Value	6		6	5	5	7	7	5	6	6	5	4	5	5	3	3	3	3	3		
	Chroma	8		8	6	6	8	8	8	8	8	8	8	6	6	2	2	1	1	1		
	Phase									**F**											S	
AME 11	Hue	1		2	2	2	2	1	1	1	1	1		1	1	1						
	Value	4		3	3	3	4	3	4	4	4	4		3	3	2,5						
	Chroma	4		3	4	4	4	6	6	6	4	4		4	2	2						
	Phase										**F**						D	F				
AME 15	Hue	1		1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	
	Value	4		4	3	3	4	5	5	4	5	5	4	4	4	4	4	3	3	3	3	
	Chroma	6		6	4	2	6	6	6	6	6	6	6	4	4	3	2	1	2	2	2	
	Phase									**F**							S					F

D = Dilation
S = Sintering
F = Fluid

F = Firing temperature

Ulong, Palau (ULG)

ULG 1

Data sheet

Fig 1-194.

Fig 1-195.

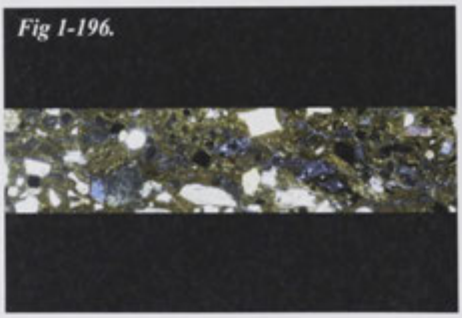


Fig 1-196.

Table 1-67. Temper data

Temper	Number of Objects	Area Fraction
Mineral	58	0.135
Glass	38	0.037
Coral	15	0.076

Table 1-68. Mineral

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	1	1.72	1	1.72
0.03-0.04	2	3.45	3	5.17
0.04-0.05	3	5.17	6	10.34
0.05-0.06	5	8.62	11	18.97
0.06-0.07	3	5.17	14	24.14
0.07-0.08	2	3.45	16	27.59
0.08-0.09	0	0	16	27.59
0.09-0.10	1	1.72	17	29.31
0.10-0.11	1	1.72	18	31.03
0.11-0.12	2	3.45	20	34.48
0.12-0.13	4	6.9	24	41.38
0.13-0.14	3	5.17	27	46.55
0.14-0.15	2	3.45	29	50
0.15-0.16	1	1.72	30	51.72
0.16-0.17	1	1.72	31	53.45
0.17-0.18	2	3.45	33	56.9

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.18-0.19	1	1.72	34	58.62
0.19-0.20	2	3.45	36	62.07
0.20-0.21	1	1.72	37	63.79
0.21-0.22	1	1.72	38	65.52
0.22-0.23	3	5.17	41	70.69
0.23-0.24	1	1.72	42	72.41
0.24-0.25	1	1.72	43	74.14
0.25-0.26	1	1.72	44	75.86
0.26-0.27	0	0	44	75.86
0.27-0.28	1	1.72	45	77.59
0.28-0.29	2	3.45	47	81.03
0.29-0.30	0	0	47	81.03
0.30-0.31	0	0	47	81.03
0.31-0.32	1	1.72	48	82.76
0.32-0.33	0	0	48	82.76
0.33-0.34	1	1.72	49	84.48
0.34-0.35	3	5.17	52	89.66
0.35-0.36	1	1.72	53	91.38
0.36-0.37	2	3.45	55	94.83
0.37-0.38	1	1.72	56	96.55
0.38-0.39	0	0	56	96.55
0.39-0.40	0	0	56	96.55
0.40-0.41	0	0	56	96.55
0.41-0.42	0	0	56	96.55
0.42-0.43	0	0	56	96.55
0.43-0.44	0	0	56	96.55
0.44-0.45	0	0	56	96.55
0.45-0.46	0	0	56	96.55
0.46-0.47	0	0	56	96.55
0.47-0.48	0	0	56	96.55
0.48-0.49	0	0	56	96.55
0.49-0.50	0	0	56	96.55
0.50-0.51	0	0	56	96.55
0.51-0.52	0	0	56	96.55
0.52-0.53	0	0	56	96.55
0.53-0.54	1	1.72	57	98.28
0.54-0.55	0	0	57	98.28
0.55-0.56	0	0	57	98.28
0.56-0.57	0	0	57	98.28
0.57-0.58	0	0	57	98.28
0.58-0.59	1	1.72	58	100

Glass

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	1	2.63	1	2.63
0.03-0.04	2	5.26	3	7.89
0.04-0.05	5	13.16	8	21.05
0.05-0.06	4	10.53	12	31.58
0.06-0.07	2	5.26	14	36.84
0.07-0.08	3	7.89	17	44.74
0.08-0.09	3	7.89	20	52.63
0.09-0.1	0	0	20	52.63
0.1-0.11	1	2.63	21	55.26
0.11-0.12	4	10.53	25	65.79
0.12-0.13	2	5.26	27	71.05
0.13-0.14	1	2.63	28	73.68
0.14-0.15	1	2.63	29	76.32
0.15-0.16	2	5.26	31	81.58
0.16-0.17	0	0	31	81.58
0.17-0.18	1	2.63	32	84.21
0.18-0.19	1	2.63	33	86.84
0.19-0.2	1	2.63	34	89.47
0.2-0.21	1	2.63	35	92.11
0.21-0.22	0	0	35	92.11
0.22-0.23	1	2.63	36	94.74
0.23-0.24	0	0	36	94.74
0.24-0.25	0	0	36	94.74
0.25-0.26	0	0	36	94.74
0.26-0.27	0	0	36	94.74
0.27-0.28	1	2.63	37	97.37
0.28-0.29	0	0	37	97.37
0.29-0.3	0	0	37	97.37
0.3-0.31	0	0	37	97.37
0.31-0.32	0	0	37	97.37
0.32-0.33	0	0	37	97.37
0.33-0.34	0	0	37	97.37
0.34-0.35	0	0	37	97.37
0.35-0.36	1	2.63	38	100

Coral

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	0	0	0	0
0.03-0.04	0	0	0	0
0.04-0.05	0	0	0	0
0.05-0.06	0	0	0	0
0.06-0.07	0	0	0	0

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.07-0.08	0	0	0	0
0.08-0.09	0	0	0	0
0.09-0.1	0	0	0	0
0.1-0.11	0	0	0	0
0.11-0.12	0	0	0	0
0.12-0.13	0	0	0	0
0.13-0.14	1	6.67	1	6.67
0.14-0.15	1	6.67	2	13.33
0.15-0.16	0	0	2	13.33
0.16-0.17	0	0	2	13.33
0.17-0.18	0	0	2	13.33
0.18-0.19	1	6.67	3	20
0.19-0.2	0	0	3	20
0.2-0.21	0	0	3	20
0.21-0.22	2	13.33	5	33.33
0.22-0.23	2	13.33	7	46.67
0.23-0.24	0	0	7	46.67
0.24-0.25	0	0	7	46.67
0.25-0.26	1	6.67	8	53.33
0.26-0.27	0	0	8	53.33
0.27-0.28	0	0	8	53.33
0.28-0.29	0	0	8	53.33
0.29-0.3	0	0	8	53.33
0.3-0.31	1	6.67	9	60
0.31-0.32	1	6.67	10	66.67
0.32-0.33	0	0	10	66.67
0.33-0.34	1	6.67	11	73.33
0.34-0.35	1	6.67	12	80
0.35-0.36	0	0	12	80
0.36-0.37	0	0	12	80
0.37-0.38	0	0	12	80
0.38-0.39	0	0	12	80
0.39-0.4	0	0	12	80
0.4-0.41	0	0	12	80
0.41-0.42	0	0	12	80
0.42-0.43	0	0	12	80
0.43-0.44	0	0	12	80
0.44-0.45	0	0	12	80
0.45-0.46	0	0	12	80
0.46-0.47	0	0	12	80
0.47-0.48	1	6.67	13	86.67
0.48-0.49	0	0	13	86.67
0.49-0.5	0	0	13	86.67
0.5-0.51	0	0	13	86.67
0.51-0.52	0	0	13	86.67
0.52-0.53	0	0	13	86.67
0.53-0.54	0	0	13	86.67
0.54-0.55	0	0	13	86.67
0.55-0.56	0	0	13	86.67
0.56-0.57	0	0	13	86.67
0.57-0.58	0	0	13	86.67
0.58-0.59	0	0	13	86.67
0.59-0.6	1	6.67	14	93.33
0.6-0.61	0	0	14	93.33
0.61-0.62	0	0	14	93.33
0.62-0.63	0	0	14	93.33
0.63-0.64	0	0	14	93.33
0.64-0.65	0	0	14	93.33
0.65-0.66	0	0	14	93.33
0.66-0.67	0	0	14	93.33
0.67-0.68	0	0	14	93.33
0.68-0.69	0	0	14	93.33
0.69-0.7	0	0	14	93.33
0.7-0.71	0	0	14	93.33
0.71-0.72	0	0	14	93.33
0.72-0.73	0	0	14	93.33
0.73-0.74	0	0	14	93.33
0.74-0.75	0	0	14	93.33
0.75-0.76	0	0	14	93.33
0.76-0.77	1	6.67	15	100

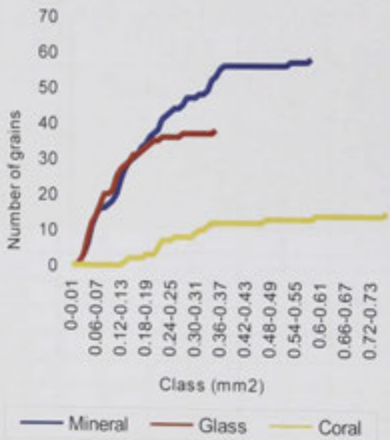


Fig 1-197. Cumulative amount of grains.

ULG 2

Data sheet

Fig 1-198.

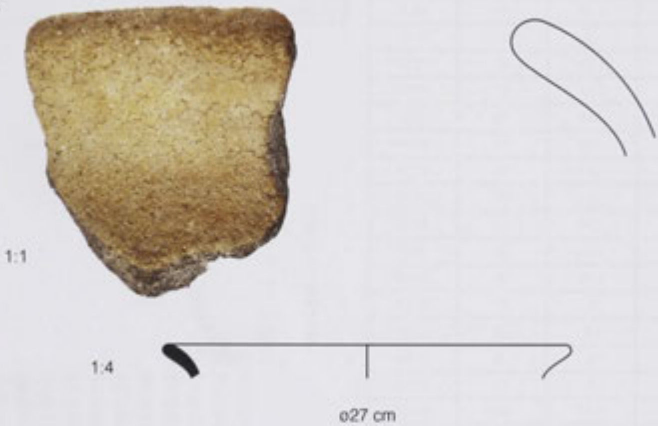


Fig 1-199.

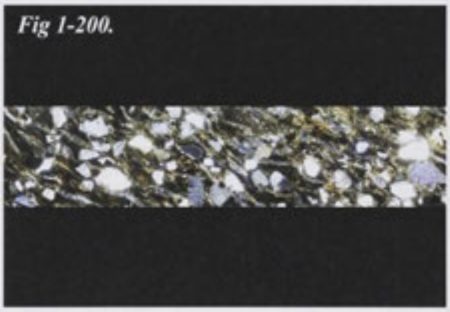


Fig 1-200.

Table 1-69. Temper data.

Temper	Number of Objects	Area Fraction
Mineral	86	0.238
Glass	4	0.002
Coral	0	0

Mineral

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	0	0	0	0
0.03-0.04	0	0	0	0
0.04-0.05	1	1.16	1	1.16
0.05-0.06	1	1.16	2	2.33
0.06-0.07	3	3.49	5	5.81
0.07-0.08	2	2.33	7	8.14
0.08-0.09	2	2.33	9	10.47
0.09-0.1	3	3.49	12	13.95
0.1-0.11	2	2.33	14	16.28
0.11-0.12	3	3.49	17	19.77
0.12-0.13	6	6.98	23	26.74
0.13-0.14	3	3.49	26	30.23
0.14-0.15	3	3.49	29	33.72
0.15-0.16	11	12.79	40	46.51
0.16-0.17	3	3.49	43	50
0.17-0.18	4	4.65	47	54.65

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.18-0.19	1	1.16	48	55.81
0.19-0.2	0	0	48	55.81
0.2-0.21	2	2.33	50	58.14
0.21-0.22	5	5.81	55	63.95
0.22-0.23	2	2.33	57	66.28
0.23-0.24	2	2.33	59	68.6
0.24-0.25	2	2.33	61	70.93
0.25-0.26	1	1.16	62	72.09
0.26-0.27	5	5.81	67	77.91
0.27-0.28	3	3.49	70	81.4
0.28-0.29	3	3.49	73	84.88
0.29-0.3	2	2.33	75	87.21
0.3-0.31	0	0	75	87.21
0.31-0.32	1	1.16	76	88.37
0.32-0.33	2	2.33	78	90.7
0.33-0.34	1	1.16	79	91.86
0.34-0.35	0	0	79	91.86
0.35-0.36	0	0	79	91.86
0.36-0.37	0	0	79	91.86
0.37-0.38	0	0	79	91.86
0.38-0.39	1	1.16	80	93.02
0.39-0.4	0	0	80	93.02
0.4-0.41	0	0	80	93.02
0.41-0.42	0	0	80	93.02
0.42-0.43	1	1.16	81	94.19
0.43-0.44	1	1.16	82	95.35
0.44-0.45	1	1.16	83	96.51
0.45-0.46	1	1.16	84	97.67
0.46-0.47	0	0	84	97.67
0.47-0.48	0	0	84	97.67
0.48-0.49	0	0	84	97.67
0.49-0.5	0	0	84	97.67
0.5-0.51	1	1.16	85	98.84
0.51-0.52	0	0	85	98.84
0.52-0.53	0	0	85	98.84
0.53-0.54	0	0	85	98.84
0.54-0.55	1	1.16	86	100

Glass

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	0	0	0	0
0.03-0.04	0	0	0	0
0.04-0.05	0	0	0	0
0.05-0.06	0	0	0	0
0.06-0.07	1	25	1	25
0.07-0.08	0	0	1	25
0.08-0.09	1	25	2	50
0.09-0.1	0	0	2	50
0.1-0.11	0	0	2	50
0.11-0.12	1	25	3	75
0.12-0.13	1	25	4	100

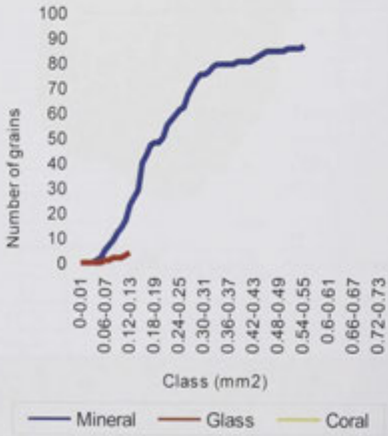


Fig 1-201. Cumulative amount of grains.

ULG 4

Data sheet

Fig 1-202.

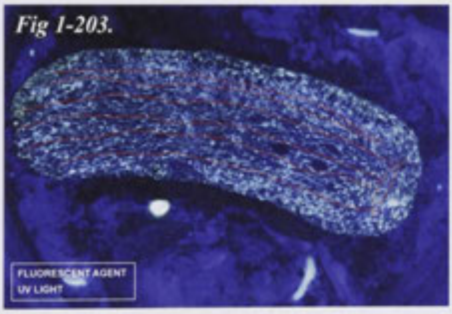


Fig 1-203.

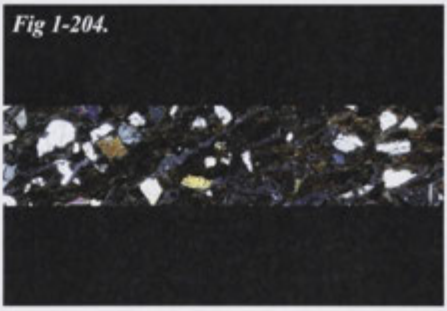


Fig 1-204.

Table 1-70. Temper data

Temper	Number of Objects	Area Fraction
Mineral	46	0.177
Glass	7	0.009
Coral	5	0.021

Mineral

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	0	0	0	0
0.03-0.04	0	0	0	0
0.04-0.05	0	0	0	0
0.05-0.06	1	2.17	1	2.17
0.06-0.07	1	2.17	2	4.35
0.07-0.08	0	0	2	4.35
0.08-0.09	0	0	2	4.35
0.09-0.1	0	0	2	4.35
0.1-0.11	2	4.35	4	8.7
0.11-0.12	2	4.35	6	13.04
0.12-0.13	0	0	6	13.04
0.13-0.14	1	2.17	7	15.22
0.14-0.15	3	6.52	10	21.74
0.15-0.16	1	2.17	11	23.91
0.16-0.17	2	4.35	13	28.26
0.17-0.18	2	4.35	15	32.61

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.18-0.19	1	2.17	16	34.78
0.19-0.2	3	6.52	19	41.3
0.2-0.21	0	0	19	41.3
0.21-0.22	0	0	19	41.3
0.22-0.23	1	2.17	20	43.48
0.23-0.24	0	0	20	43.48
0.24-0.25	1	2.17	21	45.65
0.25-0.26	1	2.17	22	47.83
0.26-0.27	0	0	22	47.83
0.27-0.28	2	4.35	24	52.17
0.28-0.29	3	6.52	27	58.7
0.29-0.3	4	8.7	31	67.39
0.3-0.31	0	0	31	67.39
0.31-0.32	2	4.35	33	71.74
0.32-0.33	1	2.17	34	73.91
0.33-0.34	1	2.17	35	76.09
0.34-0.35	0	0	35	76.09
0.35-0.36	1	2.17	36	78.26
0.36-0.37	0	0	36	78.26
0.37-0.38	2	4.35	38	82.61
0.38-0.39	0	0	38	82.61
0.39-0.4	1	2.17	39	84.78
0.4-0.41	1	2.17	40	86.96
0.41-0.42	1	2.17	41	89.13
0.42-0.43	1	2.17	42	91.3
0.43-0.44	1	2.17	43	93.48
0.44-0.45	0	0	43	93.48
0.45-0.46	0	0	43	93.48
0.46-0.47	1	2.17	44	95.65
0.47-0.48	0	0	44	95.65
0.48-0.49	0	0	44	95.65
0.49-0.5	1	2.17	45	97.83
0.5-0.51	0	0	45	97.83
0.51-0.52	0	0	45	97.83
0.52-0.53	0	0	45	97.83
0.53-0.54	0	0	45	97.83
0.54-0.55	0	0	45	97.83
0.55-0.56	0	0	45	97.83
0.56-0.57	0	0	45	97.83
0.57-0.58	0	0	45	97.83
0.58-0.59	0	0	45	97.83
0.59-0.6	0	0	45	97.83
0.6-0.61	0	0	45	97.83
0.61-0.62	0	0	45	97.83
0.62-0.63	0	0	45	97.83
0.63-0.64	1	2.17	46	100

Glass

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	0	0	0	0
0.03-0.04	0	0	0	0
0.04-0.05	0	0	0	0
0.05-0.06	1	14.29	1	14.29
0.06-0.07	0	0	1	14.29
0.07-0.08	0	0	1	14.29
0.08-0.09	0	0	1	14.29
0.09-0.1	0	0	1	14.29
0.1-0.11	0	0	1	14.29
0.11-0.12	1	14.29	2	28.57
0.12-0.13	0	0	2	28.57
0.13-0.14	1	14.29	3	42.86
0.14-0.15	1	14.29	4	57.14
0.15-0.16	1	14.29	5	71.43
0.16-0.17	0	0	5	71.43
0.17-0.18	1	14.29	6	85.71
0.18-0.19	0	0	6	85.71
0.19-0.2	1	14.29	7	100

Coral

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	0	0	0	0
0.03-0.04	0	0	0	0
0.04-0.05	0	0	0	0
0.05-0.06	0	0	0	0
0.06-0.07	0	0	0	0
0.07-0.08	0	0	0	0
0.08-0.09	0	0	0	0
0.09-0.1	0	0	0	0
0.1-0.11	0	0	0	0
0.11-0.12	0	0	0	0
0.12-0.13	0	0	0	0
0.13-0.14	0	0	0	0
0.14-0.15	0	0	0	0
0.15-0.16	0	0	0	0
0.16-0.17	0	0	0	0
0.17-0.18	0	0	0	0
0.18-0.19	0	0	0	0
0.19-0.2	0	0	0	0
0.2-0.21	0	0	0	0
0.21-0.22	1	20	1	20
0.22-0.23	0	0	1	20
0.23-0.24	0	0	1	20

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.24-0.25	1	20	2	40
0.25-0.26	0	0	2	40
0.26-0.27	0	0	2	40
0.27-0.28	1	20	3	60
0.28-0.29	0	0	3	60
0.29-0.3	0	0	3	60
0.3-0.31	1	20	4	80
0.31-0.32	0	0	4	80
0.32-0.33	0	0	4	80
0.33-0.34	0	0	4	80
0.34-0.35	0	0	4	80
0.35-0.36	1	20	5	100

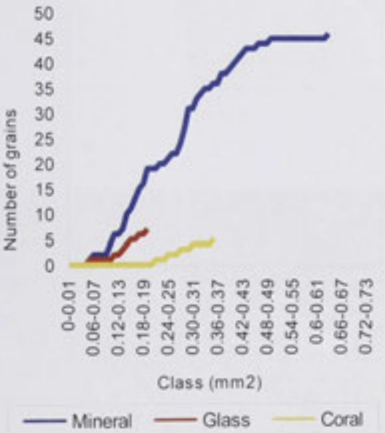


Fig 1-205. Cumulative amount of grains.

ULG 5
Data sheet

Fig 1-206.

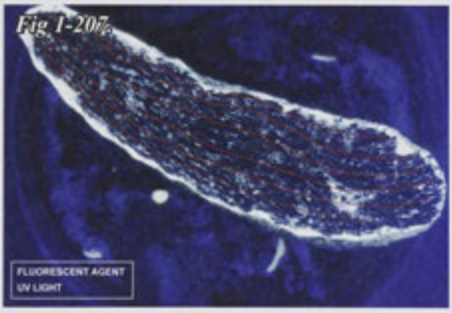


Fig 1-207.

Fig 1-208.

Table 1-71. Temper data.

Temper	Number of Objects	Area Fraction
Mineral	49	0.123
Glass	3	0.001
Coral	3	0.004

Mineral

Class (mm²)	Amount	Amount (%)	Cumulative	Cumulative (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	2	4.08	2	4.08
0.03-0.04	1	2.04	3	6.12
0.04-0.05	5	10.2	8	16.33

Class (mm²)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.05-0.06	3	6.12	11	22.45
0.06-0.07	0	0	11	22.45
0.07-0.08	4	8.16	15	30.61
0.08-0.09	3	6.12	18	36.73
0.09-0.1	2	4.08	20	40.82
0.1-0.11	3	6.12	23	46.94
0.11-0.12	1	2.04	24	48.98
0.12-0.13	1	2.04	25	51.02
0.13-0.14	0	0	25	51.02
0.14-0.15	1	2.04	26	53.06
0.15-0.16	2	4.08	28	57.14
0.16-0.17	0	0	28	57.14
0.17-0.18	0	0	28	57.14

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.18-0.19	1	2.04	29	59.18
0.19-0.2	2	4.08	31	63.27
0.2-0.21	0	0	31	63.27
0.21-0.22	1	2.04	32	65.31
0.22-0.23	0	0	32	65.31
0.23-0.24	0	0	32	65.31
0.24-0.25	0	0	32	65.31
0.25-0.26	3	6.12	35	71.43
0.26-0.27	2	4.08	37	75.51
0.27-0.28	1	2.04	38	77.55
0.28-0.29	0	0	38	77.55
0.29-0.3	0	0	38	77.55
0.3-0.31	2	4.08	40	81.63
0.31-0.32	0	0	40	81.63
0.32-0.33	1	2.04	41	83.67
0.33-0.34	1	2.04	42	85.71
0.34-0.35	0	0	42	85.71
0.35-0.36	0	0	42	85.71
0.36-0.37	1	2.04	43	87.76
0.37-0.38	0	0	43	87.76
0.38-0.39	1	2.04	44	89.8
0.39-0.4	1	2.04	45	91.84
0.4-0.41	1	2.04	46	93.88
0.41-0.42	0	0	46	93.88
0.42-0.43	0	0	46	93.88
0.43-0.44	0	0	46	93.88
0.44-0.45	0	0	46	93.88
0.45-0.46	0	0	46	93.88
0.46-0.47	1	2.04	47	95.92
0.47-0.48	0	0	47	95.92
0.48-0.49	0	0	47	95.92
0.49-0.5	0	0	47	95.92
0.5-0.51	1	2.04	48	97.96
0.51-0.52	0	0	48	97.96
0.52-0.53	0	0	48	97.96
0.53-0.54	0	0	48	97.96
0.54-0.55	0	0	48	97.96
0.55-0.56	0	0	48	97.96
0.56-0.57	0	0	48	97.96
0.57-0.58	0	0	48	97.96
0.58-0.59	0	0	48	97.96
0.59-0.6	1	2.04	49	100

Glass

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	0	0	0	0
0.03-0.04	0	0	0	0
0.04-0.05	0	0	0	0
0.05-0.06	1	33.33	1	33.33
0.06-0.07	0	0	1	33.33
0.07-0.08	0	0	1	33.33
0.08-0.09	0	0	1	33.33
0.09-0.1	0	0	1	33.33
0.1-0.11	1	33.33	2	66.67
0.11-0.12	1	33.33	3	100

Coral

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	0	0	0	0
...				
0.12-0.13	1	33.33	1	33.33
0.13-0.14	0	0	1	33.33
0.14-0.15	0	0	1	33.33
0.15-0.16	0	0	1	33.33
0.16-0.17	0	0	1	33.33
0.17-0.18	1	33.33	2	66.67
0.18-0.19	0	0	2	66.67
0.19-0.2	0	0	2	66.67
0.2-0.21	0	0	2	66.67
0.21-0.22	1	33.33	3	100

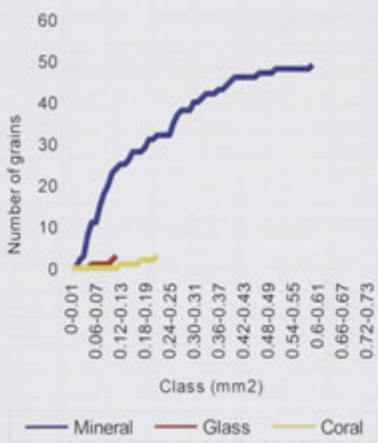


Fig 1-209. Cumulative amount of grains.

ULG 6

Data sheet

Fig 1-210.

1:1

Fig 1-211.

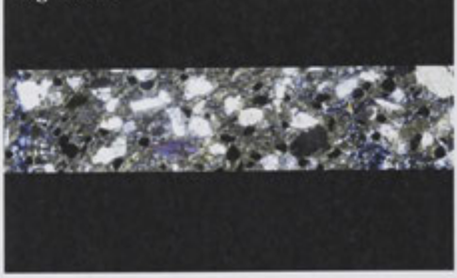


Table 1-72. Minerals

Temper	Number of Objects	Area Fraction
Mineral	77	0.202
Glass	61	0.073
Coral	21	0.073

Minerals

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	1	1.3	1	1.3
0.03-0.04	0	0	1	1.3
0.04-0.05	3	3.9	4	5.19
0.05-0.06	3	3.9	7	9.09
0.06-0.07	5	6.49	12	15.58
0.07-0.08	3	3.9	15	19.48
0.08-0.09	5	6.49	20	25.97
0.09-0.1	2	2.6	22	28.57
0.1-0.11	2	2.6	24	31.17
0.11-0.12	3	3.9	27	35.06
0.12-0.13	1	1.3	28	36.36
0.13-0.14	1	1.3	29	37.66
0.14-0.15	3	3.9	32	41.56
0.15-0.16	2	2.6	34	44.16
0.16-0.17	1	1.3	35	45.45
0.17-0.18	2	2.6	37	48.05
0.18-0.19	2	2.6	39	50.65
0.19-0.2	4	5.19	43	55.84
0.2-0.21	4	5.19	47	61.04
0.21-0.22	5	6.49	52	67.53
0.22-0.23	3	3.9	55	71.43
0.23-0.24	1	1.3	56	72.73
0.24-0.25	3	3.9	59	76.62
0.25-0.26	1	1.3	60	77.92

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.26-0.27	1	1.3	61	79.22
0.27-0.28	1	1.3	62	80.52
0.28-0.29	3	3.9	65	84.42
0.29-0.3	1	1.3	66	85.71
0.3-0.31	0	0	66	85.71
0.31-0.32	1	1.3	67	87.01
0.32-0.33	1	1.3	68	88.31
0.33-0.34	0	0	68	88.31
0.34-0.35	2	2.6	70	90.91
0.35-0.36	0	0	70	90.91
0.36-0.37	0	0	70	90.91
0.37-0.38	0	0	70	90.91
0.38-0.39	0	0	70	90.91
0.39-0.4	1	1.3	71	92.21
0.4-0.41	0	0	71	92.21
0.41-0.42	0	0	71	92.21
0.42-0.43	2	2.6	73	94.81
0.43-0.44	1	1.3	74	96.1
0.44-0.45	0	0	74	96.1
0.45-0.46	0	0	74	96.1
0.46-0.47	0	0	74	96.1
0.47-0.48	0	0	74	96.1
0.48-0.49	0	0	74	96.1
0.49-0.5	1	1.3	75	97.4
0.5-0.51	0	0	75	97.4
0.51-0.52	0	0	75	97.4
0.52-0.53	0	0	75	97.4
0.53-0.54	0	0	75	97.4
0.54-0.55	0	0	75	97.4
0.55-0.56	0	0	75	97.4
0.56-0.57	0	0	75	97.4
0.57-0.58	0	0	75	97.4
0.58-0.59	1	1.3	76	98.7
0.59-0.6	0	0	76	98.7
0.6-0.61	0	0	76	98.7
0.61-0.62	0	0	76	98.7
0.62-0.63	0	0	76	98.7
0.63-0.64	0	0	76	98.7
0.64-0.65	0	0	76	98.7
0.65-0.66	0	0	76	98.7
0.66-0.67	0	0	76	98.7
0.67-0.68	1	1.3	77	100

Glass

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	0	0	0	0
0.03-0.04	1	1.64	1	1.64
0.04-0.05	2	3.28	3	4.92
0.05-0.06	3	4.92	6	9.84
0.06-0.07	3	4.92	9	14.75
0.07-0.08	3	4.92	12	19.67
0.08-0.09	2	3.28	14	22.95
0.09-0.1	1	1.64	15	24.59
0.1-0.11	6	9.84	21	34.43
0.11-0.12	1	1.64	22	36.07
0.12-0.13	9	14.75	31	50.82
0.13-0.14	6	9.84	37	60.66
0.14-0.15	2	3.28	39	63.93
0.15-0.16	5	8.2	44	72.13
0.16-0.17	4	6.56	48	78.69
0.17-0.18	3	4.92	51	83.61
0.18-0.19	2	3.28	53	86.89
0.19-0.2	2	3.28	55	90.16
0.2-0.21	2	3.28	57	93.44
0.21-0.22	3	4.92	60	98.36
0.22-0.23	0	0	60	98.36
0.23-0.24	1	1.64	61	100

Coral

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	0	0	0	0
0.03-0.04	0	0	0	0
0.04-0.05	0	0	0	0
0.05-0.06	0	0	0	0
0.06-0.07	0	0	0	0
0.07-0.08	0	0	0	0
0.08-0.09	0	0	0	0
0.09-0.1	1	4.76	1	4.76
0.1-0.11	0	0	1	4.76
0.11-0.12	4	19.05	5	23.81
0.12-0.13	2	9.52	7	33.33
0.13-0.14	0	0	7	33.33
0.14-0.15	0	0	7	33.33
0.15-0.16	0	0	7	33.33
0.16-0.17	3	14.29	10	47.62
0.17-0.18	1	4.76	11	52.38
0.18-0.19	1	4.76	12	57.14
0.19-0.2	1	4.76	13	61.9
0.2-0.21	1	4.76	14	66.67
0.21-0.22	1	4.76	15	71.43
0.22-0.23	0	0	15	71.43
0.23-0.24	0	0	15	71.43

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.24-0.25	0	0	15	71.43
0.25-0.26	0	0	15	71.43
0.26-0.27	0	0	15	71.43
0.27-0.28	0	0	15	71.43
0.28-0.29	1	4.76	16	76.19
0.29-0.3	1	4.76	17	80.95
0.3-0.31	0	0	17	80.95
0.31-0.32	0	0	17	80.95
0.32-0.33	0	0	17	80.95
0.33-0.34	0	0	17	80.95
0.34-0.35	1	4.76	18	85.71
0.35-0.36	0	0	18	85.71
0.36-0.37	0	0	18	85.71
0.37-0.38	0	0	18	85.71
0.38-0.39	1	4.76	19	90.48
0.39-0.4	0	0	19	90.48
0.4-0.41	0	0	19	90.48
0.41-0.42	0	0	19	90.48
0.42-0.43	0	0	19	90.48
0.43-0.44	0	0	19	90.48
0.44-0.45	0	0	19	90.48
0.45-0.46	0	0	19	90.48
0.46-0.47	0	0	19	90.48
0.47-0.48	0	0	19	90.48
0.48-0.49	0	0	19	90.48
0.49-0.5	0	0	19	90.48
0.5-0.51	0	0	19	90.48
0.51-0.52	0	0	19	90.48
0.52-0.53	0	0	19	90.48
0.53-0.54	0	0	19	90.48
0.54-0.55	0	0	19	90.48
0.55-0.56	1	4.76	20	95.24
0.56-0.57	0	0	20	95.24
0.57-0.58	0	0	20	95.24
0.58-0.59	0	0	20	95.24
0.59-0.6	0	0	20	95.24
0.6-0.61	0	0	20	95.24
0.61-0.62	0	0	20	95.24
0.62-0.63	0	0	20	95.24
0.63-0.64	1	4.76	21	100

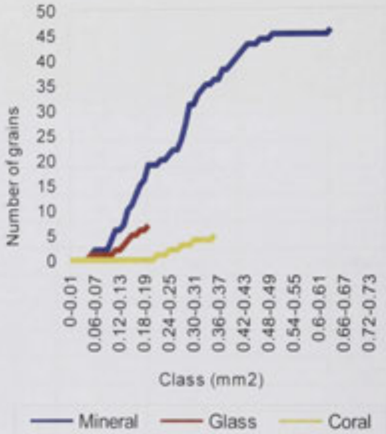


Fig 1-212. Cumulative amount of grains.

ULG 7

Data sheet

Fig 1-213.

1:1

1:4

ø22 cm

Fig 1-214.

Fig 1-215.

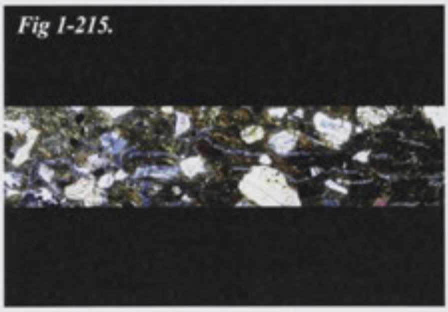


Table 1-73. Temper data.

Temper	Number of Objects	Area Fraction
Mineral	57	0.241
Glass	26	0.03
Coral	0	0

Mineral

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	2	3.51	2	3.51
0.03-0.04	2	3.51	4	7.02
0.04-0.05	3	5.26	7	12.28
0.05-0.06	3	5.26	10	17.54
0.06-0.07	2	3.51	12	21.05
0.07-0.08	2	3.51	14	24.56
0.08-0.09	3	5.26	17	29.82
0.09-0.1	0	0	17	29.82
0.1-0.11	1	1.75	18	31.58
0.11-0.12	0	0	18	31.58
0.12-0.13	0	0	18	31.58
0.13-0.14	1	1.75	19	33.33
0.14-0.15	2	3.51	21	36.84
0.15-0.16	2	3.51	23	40.35
0.16-0.17	1	1.75	24	42.11
0.17-0.18	3	5.26	27	47.37

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.18-0.19	1	1.75	28	49.12
0.19-0.2	1	1.75	29	50.88
0.2-0.21	1	1.75	30	52.63
0.21-0.22	0	0	30	52.63
0.22-0.23	2	3.51	32	56.14
0.23-0.24	3	5.26	35	61.4
0.24-0.25	0	0	35	61.4
0.25-0.26	0	0	35	61.4
0.26-0.27	1	1.75	36	63.16
0.27-0.28	2	3.51	38	66.67
0.28-0.29	2	3.51	40	70.18
0.29-0.3	1	1.75	41	71.93
0.3-0.31	0	0	41	71.93
0.31-0.32	0	0	41	71.93
0.32-0.33	1	1.75	42	73.68
0.33-0.34	0	0	42	73.68
0.34-0.35	1	1.75	43	75.44
0.35-0.36	0	0	43	75.44
0.36-0.37	1	1.75	44	77.19
0.37-0.38	2	3.51	46	80.7
0.38-0.39	2	3.51	48	84.21
0.39-0.4	0	0	48	84.21
0.4-0.41	2	3.51	50	87.72
0.41-0.42	0	0	50	87.72
0.42-0.43	1	1.75	51	89.47
0.43-0.44	0	0	51	89.47
0.44-0.45	0	0	51	89.47
0.45-0.46	0	0	51	89.47
0.46-0.47	0	0	51	89.47
0.47-0.48	0	0	51	89.47
0.48-0.49	0	0	51	89.47
0.49-0.5	0	0	51	89.47
0.5-0.51	0	0	51	89.47
0.51-0.52	1	1.75	52	91.23
0.52-0.53	0	0	52	91.23
0.53-0.54	1	1.75	53	92.98
0.54-0.55	1	1.75	54	94.74
0.55-0.56	0	0	54	94.74
0.56-0.57	0	0	54	94.74
0.57-0.58	1	1.75	55	96.49
0.58-0.59	0	0	55	96.49
0.59-0.6	0	0	55	96.49
0.6-0.61	0	0	55	96.49
0.61-0.62	0	0	55	96.49
0.62-0.63	0	0	55	96.49
0.63-0.64	1	1.75	56	98.25
0.64-0.65	0	0	56	98.25
...				

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.89-0.9	1	1.75	57	100

Glass

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	0	0	0	0
0.03-0.04	0	0	0	0
0.04-0.05	0	0	0	0
0.05-0.06	0	0	0	0
0.06-0.07	2	7.69	2	7.69
0.07-0.08	2	7.69	4	15.38
0.08-0.09	2	7.69	6	23.08
0.09-0.1	1	3.85	7	26.92
0.1-0.11	3	11.54	10	38.46
0.11-0.12	0	0	10	38.46
0.12-0.13	3	11.54	13	50
0.13-0.14	2	7.69	15	57.69
0.14-0.15	2	7.69	17	65.38
0.15-0.16	1	3.85	18	69.23
0.16-0.17	2	7.69	20	76.92
0.17-0.18	2	7.69	22	84.62
0.18-0.19	0	0	22	84.62
0.19-0.2	1	3.85	23	88.46
0.2-0.21	0	0	23	88.46
0.21-0.22	3	11.54	26	100

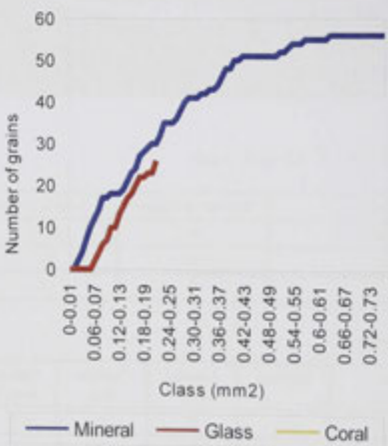


Fig 1-216. Cumulative amount of grains.

ULG 8

Data sheet

Fig 1-217.

1:1

1:4

ø22 cm

Fig 1-218.

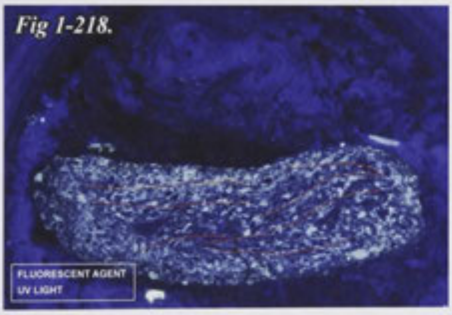


Fig 1-219.

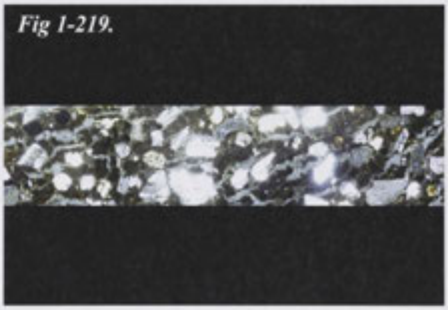


Table 1-74. Temper data

Temper	Number of Objects	Area Fraction
Mineral	73	0.255
Glass	22	0.015
Coral	8	0.034

Mineral

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	1	1.37	1	1.37
0.03-0.04	2	2.74	3	4.11
0.04-0.05	3	4.11	6	8.22
0.05-0.06	2	2.74	8	10.96
0.06-0.07	5	6.85	13	17.81
0.07-0.08	2	2.74	15	20.55
0.08-0.09	2	2.74	17	23.29
0.09-0.1	5	6.85	22	30.14
0.1-0.11	0	0	22	30.14

Temper	Number of Objects	Area Fraction
Mineral	73	0.255
Glass	22	0.015
Coral	8	0.034

Mineral

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	1	1.37	1	1.37
0.03-0.04	2	2.74	3	4.11
0.04-0.05	3	4.11	6	8.22
0.05-0.06	2	2.74	8	10.96
0.06-0.07	5	6.85	13	17.81
0.07-0.08	2	2.74	15	20.55
0.08-0.09	2	2.74	17	23.29
0.09-0.1	5	6.85	22	30.14
0.1-0.11	0	0	22	30.14
0.11-0.12	2	2.74	24	32.88
0.12-0.13	2	2.74	26	35.62
0.13-0.14	2	2.74	28	38.36
0.14-0.15	1	1.37	29	39.73
0.15-0.16	1	1.37	30	41.1
0.16-0.17	1	1.37	31	42.47
0.17-0.18	2	2.74	33	45.21
0.18-0.19	0	0	33	45.21
0.19-0.2	3	4.11	36	49.32
0.2-0.21	1	1.37	37	50.68
0.21-0.22	0	0	37	50.68
0.22-0.23	0	0	37	50.68
0.23-0.24	5	6.85	42	57.53
0.24-0.25	3	4.11	45	61.64
0.25-0.26	5	6.85	50	68.49
0.26-0.27	0	0	50	68.49
0.27-0.28	1	1.37	51	69.86
0.28-0.29	0	0	51	69.86
0.29-0.3	2	2.74	53	72.6
0.3-0.31	2	2.74	55	75.34
0.31-0.32	1	1.37	56	76.71
0.32-0.33	1	1.37	57	78.08
0.33-0.34	3	4.11	60	82.19
0.34-0.35	3	4.11	63	86.3
0.35-0.36	0	0	63	86.3
0.36-0.37	1	1.37	64	87.67
0.37-0.38	1	1.37	65	89.04
0.38-0.39	0	0	65	89.04
0.39-0.4	0	0	65	89.04
0.4-0.41	0	0	65	89.04
0.41-0.42	2	2.74	67	91.78
0.42-0.43	0	0	67	91.78
0.43-0.44	1	1.37	68	93.15
0.44-0.45	1	1.37	69	94.52
0.45-0.46	0	0	69	94.52
0.46-0.47	0	0	69	94.52
0.47-0.48	1	1.37	70	95.89
0.48-0.49	1	1.37	71	97.26
0.49-0.5	0	0	71	97.26
0.5-0.51	0	0	71	97.26
0.51-0.52	0	0	71	97.26
0.52-0.53	0	0	71	97.26
0.53-0.54	0	0	71	97.26
0.54-0.55	0	0	71	97.26
0.55-0.56	0	0	71	97.26
0.56-0.57	0	0	71	97.26
0.57-0.58	0	0	71	97.26
0.58-0.59	0	0	71	97.26
0.59-0.6	0	0	71	97.26
0.6-0.61	1	1.37	72	98.63
0.61-0.62	0	0	72	98.63
0.62-0.63	0	0	72	98.63
0.63-0.64	0	0	72	98.63
0.64-0.65	0	0	72	98.63
0.65-0.66	0	0	72	98.63
0.66-0.67	0	0	72	98.63
0.67-0.68	0	0	72	98.63
0.68-0.69	0	0	72	98.63
0.69-0.7	0	0	72	98.63
0.7-0.71	1	1.37	73	100

Glass

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	0	0	0	0
0.03-0.04	1	4.55	1	4.55
0.04-0.05	0	0	1	4.55
0.05-0.06	2	9.09	3	13.64
0.06-0.07	4	18.18	7	31.82
0.07-0.08	2	9.09	9	40.91
0.08-0.09	3	13.64	12	54.55
0.09-0.1	4	18.18	16	72.73
0.1-0.11	0	0	16	72.73
0.11-0.12	0	0	16	72.73
0.12-0.13	2	9.09	18	81.82
0.13-0.14	1	4.55	19	86.36
0.14-0.15	0	0	19	86.36

0.15-0.16	1	4.55	20	90.91
0.16-0.17	1	4.55	21	95.45
0.17-0.18	0	0	21	95.45
0.18-0.19	0	0	21	95.45
0.19-0.2	0	0	21	95.45
0.2-0.21	0	0	21	95.45
0.21-0.22	0	0	21	95.45
0.22-0.23	0	0	21	95.45
0.23-0.24	1	4.55	22	100

Coral

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	0	0	0	0
0.03-0.04	0	0	0	0
0.04-0.05	0	0	0	0
0.05-0.06	0	0	0	0
0.06-0.07	0	0	0	0
0.07-0.08	0	0	0	0
0.08-0.09	0	0	0	0
0.09-0.1	1	12.5	1	12.5
0.1-0.11	0	0	1	12.5
0.11-0.12	0	0	1	12.5
0.12-0.13	0	0	1	12.5
0.13-0.14	0	0	1	12.5
0.14-0.15	0	0	1	12.5
0.15-0.16	0	0	1	12.5
0.16-0.17	1	12.5	2	25
0.17-0.18	0	0	2	25
0.18-0.19	0	0	2	25
0.19-0.2	0	0	2	25
0.2-0.21	0	0	2	25
0.21-0.22	0	0	2	25
0.22-0.23	0	0	2	25
0.23-0.24	2	25	4	50
0.24-0.25	0	0	4	50
0.25-0.26	0	0	4	50
0.26-0.27	0	0	4	50
0.27-0.28	0	0	4	50
0.28-0.29	0	0	4	50
0.29-0.3	0	0	4	50
0.3-0.31	1	12.5	5	62.5
0.31-0.32	0	0	5	62.5
0.32-0.33	0	0	5	62.5
0.33-0.34	0	0	5	62.5
0.34-0.35	0	0	5	62.5
0.35-0.36	1	12.5	6	75
0.36-0.37	0	0	6	75

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.37-0.38	0	0	6	75
0.38-0.39	0	0	6	75
0.39-0.4	0	0	6	75
0.4-0.41	1	12.5	7	87.5
0.41-0.42	0	0	7	87.5
0.42-0.43	0	0	7	87.5
0.43-0.44	0	0	7	87.5
0.44-0.45	0	0	7	87.5
0.45-0.46	0	0	7	87.5
0.46-0.47	0	0	7	87.5
0.47-0.48	0	0	7	87.5
0.48-0.49	1	12.5	8	100

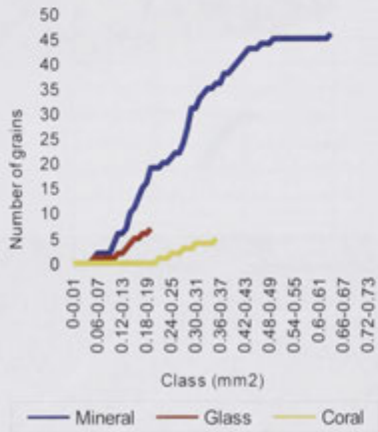


Fig 1-220. Cumulative amount of grains.

ULG 11

Data sheet

Fig 1-221.

1:1

1:4

ø44 cm

Fig 1-222.

Fig 1-223.

Table 1-75. Temper data.

Temper	Number of Objects	Area Fraction
Mineral	60	0.121
Glass	79	0.09
Coral	27	0.04

Mineral

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	0	0	0	0
0.03-0.04	2	3.33	2	3.33
0.04-0.05	0	0	2	3.33
0.05-0.06	0	0	2	3.33
0.06-0.07	1	1.67	3	5
0.07-0.08	1	1.67	4	6.67
0.08-0.09	2	3.33	6	10
0.09-0.1	0	0	6	10

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.1-0.11	3	5	9	15
0.11-0.12	0	0	9	15
0.12-0.13	6	10	15	25
0.13-0.14	2	3.33	17	28.33
0.14-0.15	4	6.67	21	35
0.15-0.16	0	0	21	35
0.16-0.17	6	10	27	45
0.17-0.18	2	3.33	29	48.33
0.18-0.19	0	0	29	48.33
0.19-0.2	3	5	32	53.33
0.2-0.21	3	5	35	58.33
0.21-0.22	4	6.67	39	65
0.22-0.23	3	5	42	70
0.23-0.24	1	1.67	43	71.67
0.24-0.25	2	3.33	45	75
0.25-0.26	1	1.67	46	76.67
0.26-0.27	1	1.67	47	78.33
0.27-0.28	1	1.67	48	80
0.28-0.29	0	0	48	80
0.29-0.3	2	3.33	50	83.33
0.3-0.31	1	1.67	51	85
0.31-0.32	2	3.33	53	88.33
0.32-0.33	1	1.67	54	90
0.33-0.34	1	1.67	55	91.67
0.34-0.35	2	3.33	57	95
0.35-0.36	0	0	57	95
0.36-0.37	0	0	57	95
0.37-0.38	1	1.67	58	96.67
0.38-0.39	1	1.67	59	98.33
0.39-0.4	0	0	59	98.33
0.4-0.41	0	0	59	98.33
0.41-0.42	0	0	59	98.33
0.42-0.43	0	0	59	98.33
0.43-0.44	0	0	59	98.33
0.44-0.45	0	0	59	98.33
0.45-0.46	0	0	59	98.33
0.46-0.47	0	0	59	98.33
0.47-0.48	0	0	59	98.33
0.48-0.49	0	0	59	98.33
0.49-0.5	0	0	59	98.33
0.5-0.51	0	0	59	98.33
0.51-0.52	0	0	59	98.33
0.52-0.53	0	0	59	98.33
0.53-0.54	1	1.67	60	100

Glass

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	0	0	0	0
0.03-0.04	1	1.27	1	1.27
0.04-0.05	1	1.27	2	2.53
0.05-0.06	2	2.53	4	5.06
0.06-0.07	1	1.27	5	6.33
0.07-0.08	3	3.8	8	10.13
0.08-0.09	3	3.8	11	13.92
0.09-0.1	7	8.86	18	22.78
0.1-0.11	7	8.86	25	31.65
0.11-0.12	13	16.46	38	48.1
0.12-0.13	3	3.8	41	51.9
0.13-0.14	7	8.86	48	60.76
0.14-0.15	7	8.86	55	69.62
0.15-0.16	5	6.33	60	75.95
0.16-0.17	2	2.53	62	78.48
0.17-0.18	4	5.06	66	83.54
0.18-0.19	1	1.27	67	84.81
0.19-0.2	1	1.27	68	86.08
0.2-0.21	3	3.8	71	89.87
0.21-0.22	2	2.53	73	92.41
0.22-0.23	1	1.27	74	93.67
0.23-0.24	1	1.27	75	94.94
0.24-0.25	1	1.27	76	96.2
0.25-0.26	0	0	76	96.2
0.26-0.27	1	1.27	77	97.47
0.27-0.28	0	0	77	97.47
0.28-0.29	0	0	77	97.47
0.29-0.3	0	0	77	97.47
0.3-0.31	0	0	77	97.47
0.31-0.32	1	1.27	78	98.73
0.32-0.33	0	0	78	98.73
0.33-0.34	0	0	78	98.73
0.34-0.35	0	0	78	98.73
0.35-0.36	0	0	78	98.73
0.36-0.37	0	0	78	98.73
0.37-0.38	0	0	78	98.73
0.38-0.39	0	0	78	98.73
0.39-0.4	0	0	78	98.73
0.4-0.41	0	0	78	98.73
0.41-0.42	0	0	78	98.73
0.42-0.43	0	0	78	98.73
0.43-0.44	1	1.27	79	100

Coral

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	0	0	0	0
0.03-0.04	0	0	0	0
0.04-0.05	0	0	0	0
0.05-0.06	0	0	0	0
0.06-0.07	0	0	0	0
0.07-0.08	0	0	0	0
0.08-0.09	0	0	0	0
0.09-0.1	0	0	0	0
0.1-0.11	1	3.7	1	3.7
0.11-0.12	2	7.41	3	11.11
0.12-0.13	1	3.7	4	14.81
0.13-0.14	1	3.7	5	18.52
0.14-0.15	1	3.7	6	22.22
0.15-0.16	1	3.7	7	25.93
0.16-0.17	2	7.41	9	33.33
0.17-0.18	4	14.81	13	48.15
0.18-0.19	2	7.41	15	55.56
0.19-0.2	2	7.41	17	62.96
0.2-0.21	3	11.11	20	74.07
0.21-0.22	3	11.11	23	85.19
0.22-0.23	1	3.7	24	88.89
0.23-0.24	1	3.7	25	92.59
0.24-0.25	0	0	25	92.59
0.25-0.26	0	0	25	92.59
0.26-0.27	1	3.7	26	96.3
0.27-0.28	0	0	26	96.3
0.28-0.29	0	0	26	96.3
0.29-0.3	0	0	26	96.3
0.3-0.31	0	0	26	96.3
0.31-0.32	0	0	26	96.3
0.32-0.33	0	0	26	96.3
0.33-0.34	0	0	26	96.3
0.34-0.35	0	0	26	96.3
0.35-0.36	0	0	26	96.3
0.36-0.37	1	3.7	27	100

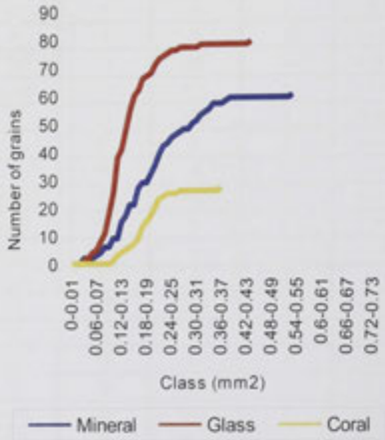


Fig 1-224. Cumulative amount of grains.

ULG 12

Data sheet

Fig 1-225.

1:1

Fig 1-226.

Fig 1-227.

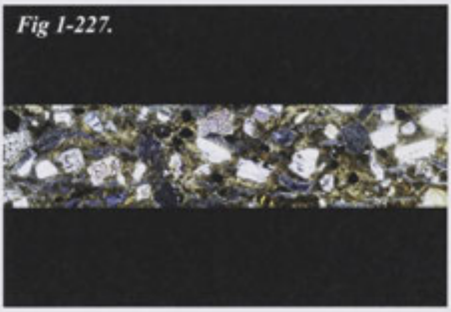


Table 1-76. Temper data.

Temper	Number of Objects	Area Fraction
Mineral	54	0.239
Glass	23	0.029
Coral	5	0.034

Mineral

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	0	0	0	0
0.03-0.04	2	3.7	2	3.7
0.04-0.05	1	1.85	3	5.56
0.05-0.06	0	0	3	5.56
0.06-0.07	0	0	3	5.56
0.07-0.08	1	1.85	4	7.41
0.08-0.09	2	3.7	6	11.11
0.09-0.1	1	1.85	7	12.96
0.1-0.11	2	3.7	9	16.67
0.11-0.12	1	1.85	10	18.52
0.12-0.13	2	3.7	12	22.22
0.13-0.14	1	1.85	13	24.07
0.14-0.15	2	3.7	15	27.78
0.15-0.16	1	1.85	16	29.63
0.16-0.17	0	0	16	29.63
0.17-0.18	2	3.7	18	33.33
0.18-0.19	0	0	18	33.33
0.19-0.2	2	3.7	20	37.04
0.2-0.21	2	3.7	22	40.74
0.21-0.22	2	3.7	24	44.44
0.22-0.23	2	3.7	26	48.15
0.23-0.24	1	1.85	27	50
0.24-0.25	2	3.7	29	53.7
0.25-0.26	2	3.7	31	57.41

Class (mm²)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.26-0.27	2	3.7	33	61.11
0.27-0.28	2	3.7	35	64.81
0.28-0.29	2	3.7	37	68.52
0.29-0.3	1	1.85	38	70.37
0.3-0.31	2	3.7	40	74.07
0.31-0.32	1	1.85	41	75.93
0.32-0.33	0	0	41	75.93
0.33-0.34	0	0	41	75.93
0.34-0.35	0	0	41	75.93
0.35-0.36	0	0	41	75.93
0.36-0.37	1	1.85	42	77.78
0.37-0.38	0	0	42	77.78
0.38-0.39	0	0	42	77.78
0.39-0.4	2	3.7	44	81.48
0.4-0.41	1	1.85	45	83.33
0.41-0.42	2	3.7	47	87.04
0.42-0.43	0	0	47	87.04
0.43-0.44	0	0	47	87.04
0.44-0.45	0	0	47	87.04
0.45-0.46	0	0	47	87.04
0.46-0.47	1	1.85	48	88.89
0.47-0.48	0	0	48	88.89
0.48-0.49	1	1.85	49	90.74
0.49-0.5	0	0	49	90.74
0.5-0.51	0	0	49	90.74
0.51-0.52	0	0	49	90.74
0.52-0.53	3	5.56	52	96.3
0.53-0.54	1	1.85	53	98.15
0.54-0.55	0	0	53	98.15
0.55-0.56	0	0	53	98.15
0.56-0.57	0	0	53	98.15
0.57-0.58	1	1.85	54	100

Glass

Class (mm²)	Amount	Amount (%)	Cumulative	Cumulative (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	0	0	0	0
0.03-0.04	0	0	0	0
0.04-0.05	1	4.35	1	4.35
0.05-0.06	2	8.7	3	13.04
0.06-0.07	1	4.35	4	17.39
0.07-0.08	5	21.74	9	39.13
0.08-0.09	1	4.35	10	43.48
0.09-0.1	0	0	10	43.48
0.1-0.11	2	8.7	12	52.17
0.11-0.12	0	0	12	52.17
0.12-0.13	0	0	12	52.17
0.13-0.14	1	4.35	13	56.52
0.14-0.15	3	13.04	16	69.57
0.15-0.16	0	0	16	69.57
0.16-0.17	0	0	16	69.57
0.17-0.18	2	8.7	18	78.26
0.18-0.19	1	4.35	19	82.61
0.19-0.2	1	4.35	20	86.96
0.2-0.21	1	4.35	21	91.3
0.21-0.22	1	4.35	22	95.65
0.22-0.23	0	0	22	95.65
0.23-0.24	0	0	22	95.65
0.24-0.25	0	0	22	95.65
0.25-0.26	0	0	22	95.65
0.26-0.27	0	0	22	95.65
0.27-0.28	0	0	22	95.65
0.28-0.29	0	0	22	95.65
0.29-0.3	0	0	22	95.65
0.3-0.31	0	0	22	95.65
0.31-0.32	0	0	22	95.65
0.32-0.33	0	0	22	95.65
0.33-0.34	0	0	22	95.65
0.34-0.35	1	4.35	23	100

Coral

Class (mm²)	Amount	Amount (%)	Cumulative	Cumulative (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	0	0	0	0
0.03-0.04	0	0	0	0
0.04-0.05	0	0	0	0
0.05-0.06	0	0	0	0
0.06-0.07	0	0	0	0
0.07-0.08	0	0	0	0
0.08-0.09	0	0	0	0
0.09-0.1	0	0	0	0
0.1-0.11	0	0	0	0
0.11-0.12	0	0	0	0
0.12-0.13	0	0	0	0
0.13-0.14	0	0	0	0
0.14-0.15	0	0	0	0
0.15-0.16	0	0	0	0
0.16-0.17	0	0	0	0
0.17-0.18	0	0	0	0
0.18-0.19	0	0	0	0
0.19-0.2	0	0	0	0
0.2-0.21	0	0	0	0

Class (mm^2)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.21-0.22	1	20	1	20
0.22-0.23	0	0	1	20
0.23-0.24	0	0	1	20
0.24-0.25	0	0	1	20
0.25-0.26	0	0	1	20
0.26-0.27	0	0	1	20
0.27-0.28	0	0	1	20
0.28-0.29	0	0	1	20
0.29-0.3	0	0	1	20
0.3-0.31	0	0	1	20
0.31-0.32	0	0	1	20
0.32-0.33	0	0	1	20
0.33-0.34	0	0	1	20
0.34-0.35	1	20	2	40
0.35-0.36	0	0	2	40
0.36-0.37	1	20	3	60
0.37-0.38	1	20	4	80
0.38-0.39	0	0	4	80
0.39-0.4	1	20	5	100

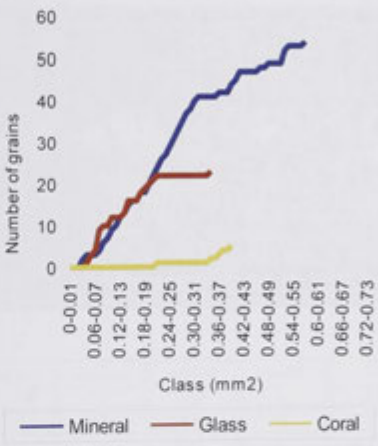


Fig 1-228. Cumulative amount of grains.

ULG 14

Data sheet

Fig 1-230.

1:1

1:4

ø40 cm


Fig 1-231.

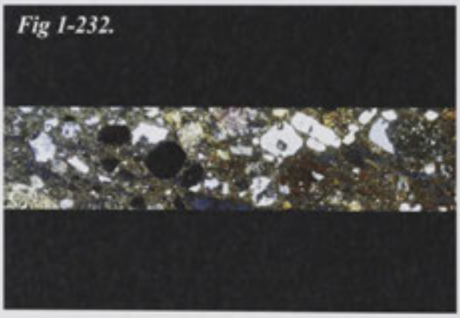


Fig 1-232.

Table 1-77. Temper data.

Temper	Number of Objects	Area Fraction
Mineral	137	0.225
Glass	1	0.024
Coral	14	0.071

Mineral

Class (mm^2)	Amount	Amount (%)	Cumulative	Cumulative (%)
0-0.01	0	0	0	0
0.01-0.02	2	1.46	2	1.46
0.02-0.03	14	10.22	16	11.68
0.03-0.04	18	13.14	34	24.82
0.04-0.05	19	13.87	53	38.69
0.05-0.06	14	10.22	67	48.91
0.06-0.07	8	5.84	75	54.74
0.07-0.08	5	3.65	80	58.39
0.08-0.09	7	5.11	87	63.5
0.09-0.1	1	0.73	88	64.23
0.1-0.11	2	1.46	90	65.69
0.11-0.12	4	2.92	94	68.61
0.12-0.13	2	1.46	96	70.07
0.13-0.14	2	1.46	98	71.53
0.14-0.15	1	0.73	99	72.26

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.15-0.16	3	2.19	102	74.45
0.16-0.17	3	2.19	105	76.64
0.17-0.18	3	2.19	108	78.83
0.18-0.19	3	2.19	111	81.02
0.19-0.2	3	2.19	114	83.21
0.2-0.21	2	1.46	116	84.67
0.21-0.22	2	1.46	118	86.13
0.22-0.23	1	0.73	119	86.86
0.23-0.24	2	1.46	121	88.32
0.24-0.25	1	0.73	122	89.05
0.25-0.26	0	0	122	89.05
0.26-0.27	1	0.73	123	89.78
0.27-0.28	3	2.19	126	91.97
0.28-0.29	2	1.46	128	93.43
0.29-0.3	0	0	128	93.43
0.3-0.31	0	0	128	93.43
0.31-0.32	0	0	128	93.43
0.32-0.33	0	0	128	93.43
0.33-0.34	1	0.73	129	94.16
0.34-0.35	0	0	129	94.16
0.35-0.36	0	0	129	94.16
0.36-0.37	0	0	129	94.16
0.37-0.38	0	0	129	94.16
0.38-0.39	1	0.73	130	94.89
0.39-0.4	0	0	130	94.89
0.4-0.41	1	0.73	131	95.62
0.41-0.42	0	0	131	95.62
0.42-0.43	0	0	131	95.62
0.43-0.44	0	0	131	95.62
0.44-0.45	0	0	131	95.62
0.45-0.46	0	0	131	95.62
0.46-0.47	0	0	131	95.62
0.47-0.48	0	0	131	95.62
0.48-0.49	1	0.73	132	96.35
0.49-0.5	0	0	132	96.35
0.5-0.51	0	0	132	96.35
0.51-0.52	0	0	132	96.35
0.52-0.53	1	0.73	133	97.08
0.53-0.54	0	0	133	97.08
0.54-0.55	0	0	133	97.08
0.55-0.56	0	0	133	97.08
0.56-0.57	0	0	133	97.08
0.57-0.58	1	0.73	134	97.81
0.58-0.59	0	0	134	97.81
0.59-0.6	0	0	134	97.81
0.6-0.61	0	0	134	97.81
0.61-0.62	1	0.73	135	98.54
0.62-0.63	0	0	135	98.54

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0.63-0.64	0	0	135	98.54
0.64-0.65	0	0	135	98.54
0.65-0.66	0	0	135	98.54
0.66-0.67	0	0	135	98.54
0.67-0.68	0	0	135	98.54
0.68-0.69	0	0	135	98.54
0.69-0.7	0	0	135	98.54
0.7-0.71	0	0	135	98.54
0.71-0.72	0	0	135	98.54
0.72-0.73	0	0	135	98.54
0.73-0.74	1	0.73	136	99.27
0.74-0.75	0	0	136	99.27
0.75-0.76	0	0	136	99.27
0.76-0.77	0	0	136	99.27
0.77-0.78	0	0	136	99.27
0.78-0.79	1	0.73	137	100

Glass

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0-0.01	0	0	0	0
...				
0.37-0.38	0	0	0	0
0.38-0.39	0	0	0	0
0.39-0.4	0	0	0	0
0.4-0.41	0	0	0	0
0.41-0.42	0	0	0	0
0.42-0.43	0	0	0	0
0.43-0.44	0	0	0	0
0.44-0.45	0	0	0	0
0.45-0.46	0	0	0	0
0.46-0.47	0	0	0	0
0.47-0.48	0	0	0	0
0.48-0.49	0	0	0	0
0.49-0.5	0	0	0	0
0.5-0.51	0	0	0	0
0.51-0.52	0	0	0	0
0.52-0.53	0	0	0	0
0.53-0.54	0	0	0	0
0.54-0.55	1	100	1	100

Coral

Class (mm²)	Amount	Amount (%)	Cumula-tive	Cumula-tive (%)
0-0.01	0	0	0	0
0.01-0.02	0	0	0	0
0.02-0.03	0	0	0	0
0.03-0.04	0	0	0	0

Class (mm²)	Amount	Amount (%)	Cumulative	Cumulative (%)
0.04-0.05	0	0	0	0
0.05-0.06	1	7.14	1	7.14
0.06-0.07	0	0	1	7.14
0.07-0.08	0	0	1	7.14
0.08-0.09	0	0	1	7.14
0.09-0.1	1	7.14	2	14.29
0.1-0.11	0	0	2	14.29
0.11-0.12	0	0	2	14.29
0.12-0.13	1	7.14	3	21.43
0.13-0.14	0	0	3	21.43
0.14-0.15	1	7.14	4	28.57
0.15-0.16	0	0	4	28.57
0.16-0.17	1	7.14	5	35.71
0.17-0.18	0	0	5	35.71
0.18-0.19	1	7.14	6	42.86
0.19-0.2	0	0	6	42.86
0.2-0.21	0	0	6	42.86
0.21-0.22	1	7.14	7	50
0.22-0.23	1	7.14	8	57.14
0.23-0.24	0	0	8	57.14
0.24-0.25	0	0	8	57.14
0.25-0.26	0	0	8	57.14
0.26-0.27	0	0	8	57.14
0.27-0.28	0	0	8	57.14
0.28-0.29	1	7.14	9	64.29
0.29-0.3	1	7.14	10	71.43
0.3-0.31	1	7.14	11	78.57
0.31-0.32	0	0	11	78.57
0.32-0.33	0	0	11	78.57
0.33-0.34	0	0	11	78.57
0.34-0.35	0	0	11	78.57
0.35-0.36	0	0	11	78.57
0.36-0.37	0	0	11	78.57
0.37-0.38	0	0	11	78.57
0.38-0.39	0	0	11	78.57
0.39-0.4	0	0	11	78.57
0.4-0.41	0	0	11	78.57
0.41-0.42	0	0	11	78.57
0.42-0.43	0	0	11	78.57
0.43-0.44	1	7.14	12	85.71
0.44-0.45	0	0	12	85.71
0.45-0.46	0	0	12	85.71
0.46-0.47	0	0	12	85.71
0.47-0.48	0	0	12	85.71
0.48-0.49	0	0	12	85.71
0.49-0.5	0	0	12	85.71
0.5-0.51	0	0	12	85.71
0.51-0.52	0	0	12	85.71
0.52-0.53	0	0	12	85.71
0.53-0.54	0	0	12	85.71
0.54-0.55	0	0	12	85.71
0.55-0.56	0	0	12	85.71
0.56-0.57	0	0	12	85.71
0.57-0.58	0	0	12	85.71
0.58-0.59	0	0	12	85.71
0.59-0.6	1	7.14	13	92.86
0.6-0.61	0	0	13	92.86
0.61-0.62	0	0	13	92.86
0.62-0.63	0	0	13	92.86
0.63-0.64	0	0	13	92.86
0.64-0.65	0	0	13	92.86
0.65-0.66	0	0	13	92.86
0.66-0.67	0	0	13	92.86
0.67-0.68	0	0	13	92.86
0.68-0.69	0	0	13	92.86
0.69-0.7	0	0	13	92.86
0.7-0.71	0	0	13	92.86
0.71-0.72	0	0	13	92.86
0.72-0.73	1	7.14	14	100

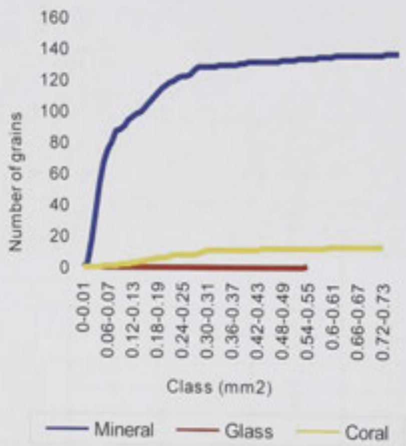
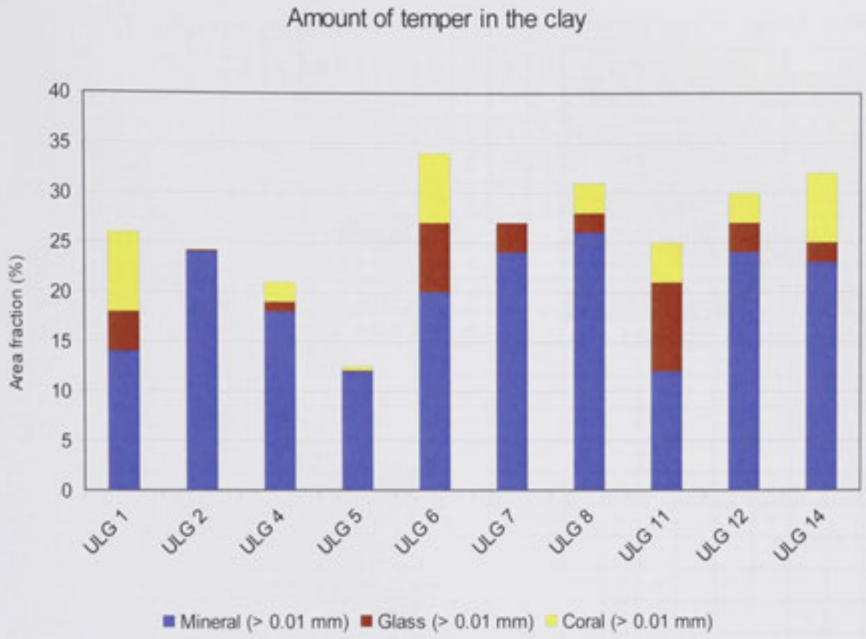


Fig 1-229. Cumulative amount of grains.


Amount of temper in the clay
Area fraction (%)
0
5
10
15
20
25
30
35
40
ULG 1
ULG 2
ULG 4
ULG 5
ULG 6
ULG 7
ULG 8
ULG 11
ULG 12
ULG 14
Mineral (> 0.01 mm)
Glass (> 0.01 mm)
Coral (> 0.01 mm)

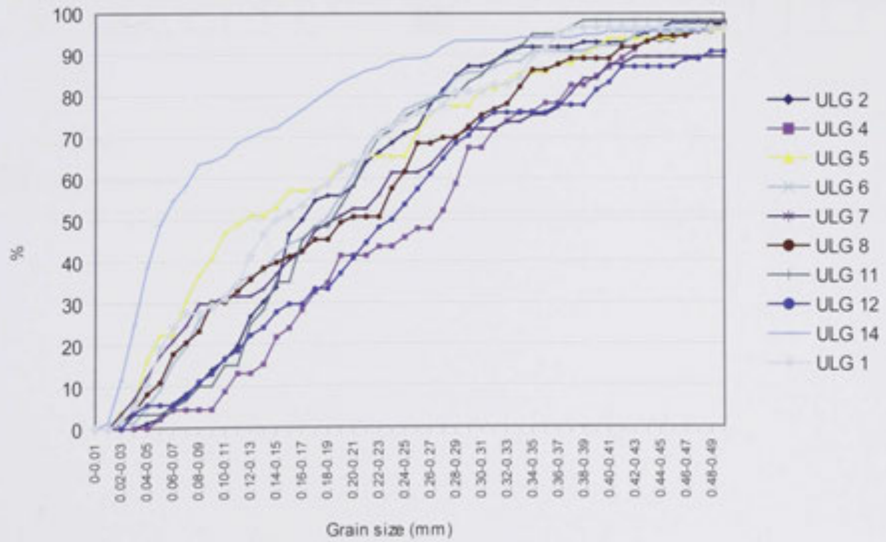

%
0
10
20
30
40
50
60
70
80
90
100
Grain size (mm)
ULG 2
ULG 4
ULG 5
ULG 6
ULG 7
ULG 8
ULG 11
ULG 12
ULG 14
ULG 1

Table 1-78. Result of pore line analysis..

Lab. no.	Maufacturing technique
ULG 1	Paddle and anvil
ULG 2	Paddle and anvil
ULG 3	Paddle and anvil
ULG 5	Paddle and anvil
ULG 6	Not analysed
ULG 7	Paddle and anvil
ULG 8	Paddle and anvil
ULG 11	Paddle and anvil
ULG 12	Paddle and anvil
ULG 14	Paddle and anvil

Table 1-79. Thermal test results.

	Temperature (°C)	20	100	200	300	400	500	600	700	800	900	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500
ULG 1	Hue	4		4	4	4	4	4	4	2	2	2	2	2	2	2	3	4				
	Value	7		7	7	6	5	7	7	7	7	7	7	8	7	7	4	3				
	Chroma	4		6	6	4	4	4	6	6	6	6	4	4	4	3	2	1				
	Phase							F	F	X							D		S			
ULG 3	Hue	6		6	6	5	6	2	2	2	1	2										
	Value	2.5		3	3	3	3	5	4	5	6	7										
	Chroma	2		2	2	2	2	4	4	6	8	6										
	Phase						F															
ULG 4	Hue	4		4	4	4	4	4	4	2	2	2	2	2	2	2						
	Value	3		7	7	6	5	4	3	6	6	7	7	7	7	4						
	Chroma	3		6	6	4	4	4	3	6	6	6	4	6	3	3						
	Phase								F						D		S					
ULG 6	Hue	5		5	4	4	4	5	5	2	2	2	2	2	2	3	3	3	4			
	Value	6		6	6	6	7	7	6	6	7	7	7	6	7	8	4	4	3			
	Chroma	4		4	4	4	4	4	4	6	6	8	6	6	3	4	1	1	1			
	Phase								F		X							D		S		
ULG 14	Hue	3		4	4	4	4	4	4	3	2	2	2	2	2	3						
	Value	7		7	7	7	6	6	6	7	7	8	7	8	7	8						
	Chroma	4		6	6	4	4	4	3	4	6	4	4	3	3	2						
	Phase									F/X						D	S					

D = Dilation
S = Sintering
F = Fluid

X = Sample cracks

F = Firing temperature

Appendix 2:
Lithics

Contents

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9:10

Scale 1:1

11:1

11:2

11:3

11:4

11:5

11:6

11:7

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11:10

11:11

11:12

12:1

12:2

12:3

12:4

12:5

12:6

15:1

Scale 1:1

16:1

17:1

18:1

18:2

18:3

18:4

18:5

18:6

18:7

Scale 1:1


22:1


22:2


22:3


22:4


22:5


22:6


22:7


23:1


23:2


23:3


23:4

Scale 1:1


24:1


24:2


24:3


24:4


26:1


30:1


30:2


37:1


37:2


37:3


37:4


40:1


42:1


42:2


42:3


42:4


42:5


42:6


42:7


42:8


42:9

Scale 1:1

45:1

45:2

46

47:1

49:1

49:2

50:1

50:2

58:1

58: 2

58: 3

Scale 1:1

60:1

61:1

62:1

62:2

62:3

62:4

64:1

Scale 1:1


67:1


67:2


74:1


70:1


70:2


70:3


73:1


85:1


85:2


89:1


90:1


90:2

Scale 1:1

91:1

91:2

91:3

91:4

95:1

95:2

97:1

97:2

Scale 1:1

97:3

97:4

97:5

Scale 1:1

99:1

Scale 1:2

100:1

100:2

100:3

100:4

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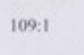

109:1

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Scale 1:1

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117:1

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122:1

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Scale 1:1

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Scale 1:1


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132:1


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133:1


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133:3

Scale 1:1

136:1

136:2

136:3

136:4

136:5

136:6

138:1

138:2

139:1

139:2

139:3

139:4

Scale 1:1


140:1


140:2


140:3


140:4


140:5


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Scale 1:1

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141:6

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143:1

Scale 1:1

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144:2

145:1

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146:2

146:3

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Scale 1:1


147:1


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147:3


147:4


147:5


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151:1


151:2


151:3

Scale 1:1

152:1

152:2

152:3

152:4

152:5

152:6

152:7

152:8

Scale 1:1

153:1

Scale 1:1


153:2


153:3


153:4


153:5


153:6


154:1


154:2


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Scale 1:1

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Scale 1:1


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156

Scale 1:1


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158:2


158:3


158:4


158:5


158:6


159:1


159:2


159:3

Scale 1:1

160:1

160:2

Scale 1:1

161:1

161:2

161:3

161:4

161:5

161:6

161:7

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161:9

161:10

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Scale 1:1


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Scale 1:1

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Scale 1:1

164:1

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166:3

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Scale 1:1


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171:1


171:2

Scale 1:1

172:1

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172:3

172:4

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Scale 1:1

173:1

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175:1

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Scale 1:1

List of finds

Cat. No.	Depth (cm)	Unit	Category	Weight (g)	Comment	Petro-graphic study	Photo
1:1	23-35	1	Sling Stone	92			x
2:1	23-35	2	–	–			x
2:2	23-35	2	–	–			x
8:1	23-35	8	–	–			x
8:2	23-35	8	–	–			x
9:1	23-35	9	–	–			x
9:2	23-35	9	–	–			x
9:3	23-35	9	–	–			x
9:4	23-35	9	–	–			x
9:5	23-35	9	–	–			x
9:6	23-35	9	–	–		x	x
9:7	23-35	9	–	–			x
9:8	23-35	9	–	–			x
9:9	23-35	9	–	–			x
9:10	23-35	9	–	–			x
11:1	35-50	2	–	–			x
11:2	35-50	2	–	–			x
11:3	35-50	2	–	–			x
11:4	35-50	2	–	–			x
11:5	35-50	2	–	–			x
11:6	35-50	2	–	–			x
11:7	35-50	2	–	–			x
11:8	35-50	2	–	–			x
11:9	35-50	2	–	–			x
11:10	35-50	2	–	–			x
11:11	35-50	2	–	–			x
11:12	35-50	2	–	–			x
12:1	35-50	3	–	–			x
12:2	35-50	3	–	–			x
12:3	35-50	3	–	–			x
12:4	35-50	3	–	–			x
12:5	35-50	3	–	–			x
12:6	35-50	3	–	–			x
15:1	35-50	6	Adze	8	Fragment		x
16:1	35-50	7	Adze	38	Fragment	x	x
17:1	35-50	8	Sling Stone	58			x
18:1	35-50	9	–	–			x
18:2	35-50	9	–	–			x

Cat. No.	Depth (cm)	Unit	Category	Weight (g)	Comment	Petro-graphic study	Photo
18:3	35-50	9	–	–			x
18:4	35-50	9	–	–			x
18:5	35-50	9	–	–			x
18:6	35-50	9	–	–			x
18:7	35-50	9	–	–		x	x
22:1	50-65	4	–	–			x
22:2	50-65	4	–	–			x
22:3	50-65	4	–	–			x
22:4	50-65	4	–	–			x
22:5	50-65	4	–	–			x
22:6	50-65	4	–	–			x
22:7	50-65	4	–	–			x
23:1	50-65	5	–	–			x
23:2	50-65	5	–	–			x
23:3	50-65	5	–	–			x
23:4	50-65	5	–	–			x
24:1	50-65	6	–	–			x
24:2	50-65	6	–	–			x
24:3	50-65	6	–	–			x
24:4	50-65	6	–	–			x
26:1	50-65	8	–	2		x	x
30:1	65-80	3	–	–			x
30:2	65-80	3	–	–			x
37:1	80-90	1	–	–			x
37:2	80-90	1	–	–			x
37:3	80-90	1	–	–			x
37:4	80-90	1	–	–			x
40:1	80-90	4	–	22			x
41:1	80-90	5	–	9			
42:1	80-90	6	–	–			x
42:2	80-90	6	–	–			x
42:3	80-90	6	–	–			x
42:4	80-90	6	–	–			x
42:5	80-90	6	–	–			x
42:6	80-90	6	–	–			x
42:7	80-90	6	–	–			x
42:8	80-90	6	–	–			x
42:9	80-90	6	–	–			x
43:1	80-90	7	–	16			
45:1	80-90	9	–	–			x
45:2	80-90	9	–	–			x
46:1	90-100	1	–	27			x
47:1	90-100	2	–	1			
49:1	90-100	4	–	–			x
49:2	90-100	4	–	–			x
50:1	90-100	5	–	–			x

Cat. No.	Depth (cm)	Unit	Category	Weight (g)	Comment	Petro-graphic study	Photo
50:2	90-100	5	–	–			x
58:1	100-110	4	–	–			x
58:2	100-110	4	–	–			x
58:3	100-110	4	–	–			x
60:1	100-110	6	–	1			x
61:1	100-110	7	–	118			x
62:1	100-110	8	–	–			x
62:2	100-110	8	–	–			x
62:3	100-110	8	–	–			x
62:4	100-110	8	–	–			x
64:1	110-120	1	Adze	120	Fragment	x	x
67:1	110-120	4	–	–			x
67:2	110-120	4	–	–			x
70:1	110-120	7	–	–			x
70:2	110-120	7	–	–			x
70:3	110-120	7	–	–			x
73:1	120-130	1	–	12			x
74:1	120-130	2	–			x	x
85:1	130-140	5	–				x
85:2	130-140	5	–				x
89:1	140-150	1	–	12			x
90:1	140-150	2	–	–			x
90:2	140-150	2	–	–			x
91:1	140-150	3	Adze	36		x	x
91:2	140-150	3	–	–			x
91:3	140-150	3	–	–			x
91:4	140-150	3	–	–			x
95:1	140-150	7	–				x
95:2	140-150	7	–				x
97:1	150-160	1	–				x
97:2	150-160	1	–				x
97:3	150-160	1	Adze	478		x	x
97:4	150-160	1	Adze	14	Fragment	x	x
97:5	150-160	1	Adze	30	Fragment		x
	150-160		–				
99:1	150-160	3	Adze	1064		x	x
100:1	150-160	4	–	–			x
100:2	150-160	4	–	–			x
100:3	150-160	4	–	–			x
100:4	150-160	4	–	–			x
102:1	150-160	6	–	6			x
105:1	160-170	1	–	100			x
108:1	160-170	4	Net sinker/Pendant	50			x
109:1	160-170	5	–	–			x
109:2	160-170	5	–	–			x
109:3	160-170	5	–	–			x

Cat. No.	Depth (cm)	Unit	Category	Weight (g)	Comment	Petro-graphic study	Photo
109:4	160-170	5	–	–			x
112:1	160-170	8	Retouch stone	1			x
114:1	170-180	2	Sling stone/grinding stone	50			x
115:1	170-180	3	–	–			x
117:1	170-180	5	–	–			x
117:2	170-180	5	–	–			x
117:3	170-180	5	–	–			x
118:1	170-180	6	–	2			x
122:1	180-190	2	–	–			x
122:2	180-190	2	–	–			x
125:1	180-190	5	–	–			x
125:2	180-190	5	–	–			x
127:1	180-190	7	–	1			x
128:1	180-190	8	–	–			x
128:2	180-190	8	–	–			x
129:1	190-200	1	Adze	212			x
129:2	190-200	1	–	–			x
130:1	190-200	2	–	–			x
130:2	190-200	2	–	–			x
130:3	190-200	2	–	–			x
130:4	190-200	2	–	–			x
130:5	190-200	2	–	–			x
130:6	190-200	2	–	–			x
130:7	190-200	2	–	–			x
130:8	190-200	2	–	–			x
130:9	190-200	2	–	–			x
131:1	190-200	3	–	–			x
131:2	190-200	3	–	–			x
131:3	190-200	3	–	–			x
131:4	190-200	3	–	–			x
131:5	190-200	3	Adze	16	Flake		x
132:1	190-200	4	–	–			x
132:2	190-200	4	–	–			x
132:3	190-200	4	–	–		x	x
133:1	190-200	5	–	–			x
133:2	190-200	5	–	–			x
133:3	190-200	5	Worked coral	230			x
136:1	190-200	6	Adze	24			x
136:2	190-200	6	Sinker/Pendant	4			x
136:3	190-200	6	–	–			x
136:4	190-200	6	–	–			x
136:5	190-200	6	–	–		x	x
136:6	190-200	6	Adze	42	Fragment		x
138:1	200-210	1	–	–			x
138:2	200-210	1	–	–			x
139:1	200-210	2	–	–			x

Cat. No.	Depth (cm)	Unit	Category	Weight (g)	Comment	Petro-graphic study	Photo
139:2	200-210	2	–	–			x
139:3	200-210	2	–	–			x
139:4	200-210	2	–	–			x
140:1	200-210	3	–	–			x
140:2	200-210	3	–	–			x
140:3	200-210	3	–	–			x
140:4	200-210	3	–	–			x
140:5	200-210	3	–	–			x
140:6	200-210	3	–	–			x
140:7	200-210	3	–	–			x
140:8	200-210	3	–	–			x
140:9	200-210	3	–	–			x
140:10	200-210	3	–	–			x
140:11	200-210	3	–	–			x
140:12	200-210	3	–	–			x
140:13	200-210	3	–	–			x
140:14	200-210	3	–	–			x
140:15	200-210	3	–	–			x
140:16	200-210	3	–	–			x
141:1	200-210	4	–	–			x
141:2	200-210	4	–	–			x
141:3	200-210	4	–	–			x
141:4	200-210	4	–	–			x
141:5	200-210	4	–	–			x
141:6	200-210	4	–	–			x
142:1	200-210	5	–	–			x
142:2	200-210	5	–	–			x
142:3	200-210	5	–	–			x
142:4	200-210	5	–	–			x
142:5	200-210	5	–	–			x
142:6	200-210	5	–	–			x
143:1	200-210	6	Sling stone?	92			x
144:1	200-210	7	Adze	22			x
144:2	200-210	7	Adze	42			x
145:1	200-210	8	–	4			x
146:1	210-220	1	–	–			x
146:2	210-220	1	–	–			x
146:3	210-220	1	–	–			x
146:4	210-220	1	–	–			x
146:5	210-220	1	–	–			x
146:6	210-220	1	–	–			x
146:7	210-220	1	–	–			x
146:8	210-220	1	–	–			x
146:9	210-220	1	–	–			x
146:10	210-220	1	–	–			x
146:11	210-220	1	–	–			x

Cat. No.	Depth (cm)	Unit	Category	Weight (g)	Comment	Petro-graphic study	Photo
146:12	210-220	1	–	–			x
146:13	210-220	1	–	–			x
147:1	210-220	2	–	–			x
147:2	210-220	2	–	–			x
147:3	210-220	2	–	–			x
147:4	210-220	2	–	–			x
147:5	210-220	2	–	–			x
147:6	210-220	2	–	–			x
148:1	210-220	3	–	30			
151:1	210-220	6	–	–			x
151:2	210-220	6	Worked stone	–			x
151:3	210-220	6	Worked stone	112		x	x
152:1	210-220	7	Adze	40			x
152:2	210-220	7	Adze	80		x	x
152:3	210-220	7	–	–			x
152:4	210-220	7	–	–			x
152:5	210-220	7	–	–			x
152:6	210-220	7	–	–			x
152:7	210-220	7	–	–			x
152:8	210-220	7	–	–			x
153:1	210-220	8	Pounder?	934		x	x
153:2	210-220	8	–	–			x
153:3	210-220	8	–	–			x
153:4	210-220	8	–	–			x
153:5	210-220	8	–	–			x
153:6	210-220	8	–	–			x
154:1	220-230	1	–	–			x
154:2	220-230	1	–	–			x
154:3	220-230	1	–	–			x
154:4	220-230	1	–	–			x
154:5	220-230	1	–	–			x
154:6	220-230	1	–	–			x
154:7	220-230	1	–	–			x
154:8	220-230	1	–	–			x
154:9	220-230	1	–	–			x
154:10	220-230	1	–	–			x
154:11	220-230	1	–	–			x
154:12	220-230	1	–	–			x
154:13	220-230	1	–	–			x
154:14	220-230	1	–	–			x
154:15	220-230	1	–	–			x
154:16	220-230	1	–	–			x
154:17	220-230	1	–	–			x
154:18	220-230	1	Worked stone	–		x	x
155:1	220-230	2	–	–			x
155:2	220-230	2	–	–			x

Cat. No.	Depth (cm)	Unit	Category	Weight (g)	Comment	Petro-graphic study	Photo
155:3	220-230	2	–	–			x
155:4	220-230	2	–	–			x
155:5	220-230	2	–	–			x
155:6	220-230	2	–	–			x
155:7	220-230	2	–	–			x
155:8	220-230	2	–	–			x
155:9	220-230	2	–	–			x
155:10	220-230	2	–	–			x
155:11	220-230	2	–	–			x
155:12	220-230	2	–	–			x
155:13	220-230	2	–	–			x
155:14	220-230	2	–	–			x
155:15	220-230	2	–	–			x
155:16	220-230	2	–	–			x
155:17	220-230	2	–	–			x
155:18	220-230	2	–	–			x
155:19	220-230	2	–	–			x
155:20	220-230	2	–	–			x
155:21	220-230	2	–	–			x
155:22	220-230	2	–	–			x
156:1	230-240	1	Adze	112			x
157:1	220-230	3	–	–			
157:2	220-230	3	–	–			
157:3	220-230	3	–	–			
157:4	220-230	3	–	–			
157:5	220-230	3	–	–			
157:6	220-230	3	–	–			
157:7	220-230	3	–	–			
157:8	220-230	3	–	–			
157:9	220-230	3	–	–			
157:10	220-230	3	–	–			
157:11	220-230	3	–	–			
157:12	220-230	3	–	–			
157:13	220-230	3	–	–			
157:14	220-230	3	–	–			
157:15	220-230	3	–	–			
157:16	220-230	3	–	–			
158:1	220-230	4	–	–			x
158:2	220-230	4	–	–			x
158:3	220-230	4	–	–			x
158:4	220-230	4	–	–			x
158:5	220-230	4	–	–			x
158:6	220-230	4	–	–			x
159:1	220-230	5	–	–			x
159:2	220-230	5	–	–			x
159:3	220-230	5	–	–			x

Cat. No.	Depth (cm)	Unit	Category	Weight (g)	Comment	Petro-graphic study	Photo
159:3	220-230	5	–	–			x
160:1	220-230	6	Adze	112		x	x
160:2	220-230	6	Adze	44			x
161:1	230-240	2	Adze	60		x	x
161:2	230-240	2	Adze	36			x
161:3	230-240	2	–	–			x
161:4	230-240	2	–	–			x
161:5	230-240	2	–	–			x
161:6	230-240	2	–	–			x
161:7	230-240	2	–	–			x
161:8	230-240	2	–	–			x
161:9	230-240	2	–	–			x
161:10	230-240	2	–	–			x
161:11	230-240	2	–	–			x
162:1	230-240	3	–	–			x
162:2	230-240	3	–	–			x
162:3	230-240	3	–	–			x
162:4	230-240	3	–	–			x
162:5	230-240	3	–	–			x
162:6	230-240	3	–	–			x
162:7	230-240	3	–	–			x
162:8	230-240	3	–	–			x
162:9	230-240	3	–	–			x
162:10	230-240	3	–	–			x
163:1	230-240	4	Worked stone	392		x	x
163:2	230-240	4	Debitage	30		x	x
163:3	230-240	4	–	–			x
163:4	230-240	4	–	–			x
163:5	230-240	4	–	–			x
163:6	230-240	4	–	–			x
163:7	230-240	4	–	–			x
163:8	230-240	4	–	–			x
163:9	230-240	4	–	–			x
163:10	230-240	4	–	–			x
163:11	230-240	4	–	–			x
164:1	240-250	1	Adze	12			x
165:1	240-250	2	–	–			x
165:2	240-250	2	–	–			x
165:3	240-250	2	–	–			x
165:4	240-250	2	–	–			x
166:1	240-250	3	–	–			x
166:2	240-250	3	–	–			x
166:3	240-250	3	–	–		x	x
167:1	250-260	2	–	–			x
167:2	250-260	2	–	–			x
167:3	250-260	2	–	–			x

Cat. No.	Depth (cm)	Unit	Category	Weight (g)	Comment	Petro-graphic study	Photo
168:1	250-260	3	–	–			x
168:2	250-260	3	–	–			x
169:1	240-250	4	–	–			x
169:2	240-250	4	–	–			x
169:3	240-250	4	–	–			x
169:4	240-250	4	–	–			x
170:1	230-240	5	–	–			x
170:2	230-240	5	–	–			x
170:3	230-240	5	–	–			x
170:4	230-240	5	–	–			x
170:5	230-240	5	–	–			x
170:6	230-240	5	–	–			x
171:1	230-240	6	Adze	210			x
171:2	230-240	6	–	–		x	x
172:1	240-250	5	–	–		x	x
172:2	240-250	5	–	–			x
172:3	240-250	5	–	–			x
172:4	240-250	5	–	–			x
172:5	240-250	5	–	–			x
172:6	240-250	5	–	–			x
172:7	240-250	5	–	–			x
172:8	240-250	5	–	–			x
172:9	240-250	5	–	–			x
172:10	240-250	5	–	–			
173:1	240-250	6	Worked stone/Core	64			x
174:1	250-260	4	–	–			x
174:2	250-260	4	–	–			x
175:1	250-260	5	Adze	56		x	x
176:1	250-260	6	Adze	32	Flake	x	x

Lithics weight matrix

Depth	U1	U2	U3	U4	U5	U6	U7	U8	U9
23-35	92	18						19	48
35-50		36	12			8	38	58	70
50-65				36	146			2	
65-80			46						
80-90	26			22	9	68	16		14
90-100	27	1		36	10				
100-110				114		1	118	28	
110-120	120			4			24		
120-130	12	30							BURI-AL
130-140									
140-150	12	4	50						
150-160	692		464	34		6			
160-170	100			50	12			1	
170-180		50			26	2			
180-190		4			12		1	4	
190-200	212	48	16	26	246		70		
200-210	10	12	128	16	140	93	64	4	
210-220	28	22	30			112	150	934	
220-230	186	152	112	30	8	156			
230-240	112	96	22	580	22	210			
240-250	12	25	78	6	60	64			
250-260		16	16	8	56	32			

Thin Section Study of Lithic Material from Bapot with microscopic descriptions

by Geoff Hunt

Metamorphic/sedimentary

Cat. No. 160:1

Very fine grained amorphous rock with prominent vein fills of irregular fractures. Quartz/silica/possible calcite infill. At higher magnification a fine granular to amorphous texture is visible. The granular texture seems composed of small equidimensional and equigranular grains packed closely together.

A banding of rock is visible on the thin section by eye and this banded is defined under magnification by variations of the grain size. Larger grains ~0.05 mm in diameter and smaller grains half that dimension. There are differing grains ~0.10 mm with a more angular and less equidimensional form.

Fig 2-1. Cat. No. 160:1.

Table 2-1. Description of samples.

Photo#	Polarization	Size of image	Description
214	XP	1.5 mm	Thin section showing fractures containing quartz vein fill. The groundmass is amorphous with microcrystals.
219	PP	1.5 mm	Thin section showing fractures containing quartz vein fill (clear horizontal band) in rock with granular texture.
221	PP	1 mm	A view of the granular amorphous texture of rock.
223	XP	1 mm	At higher magnification the evidence of significant alteration is visible in the brown discolouration over much of the view. Crystals are visible within this material.
224	XP	4 mm	A view of the veins and groundmass showing that there are many microcrystals within the groundmass.
227	PP	4 mm	In plain light the groundmass looks more amorphous with dark flecks being opaque mineral grains.

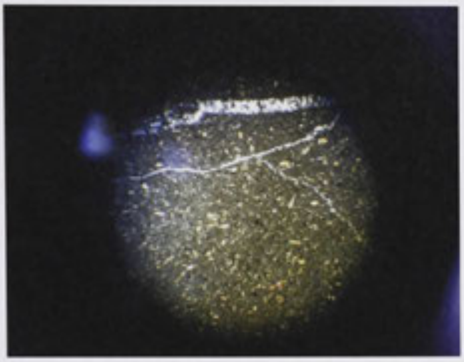


Fig 2-2. Photo #214.

Fig 2-3. Photo #219.

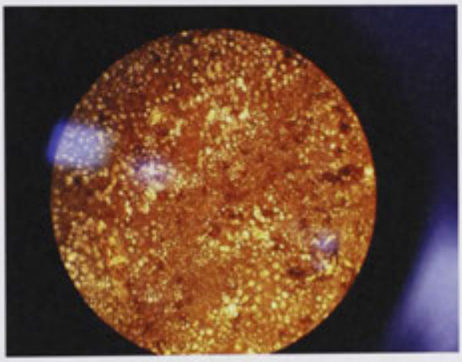


Fig 2-4. Photo #221.

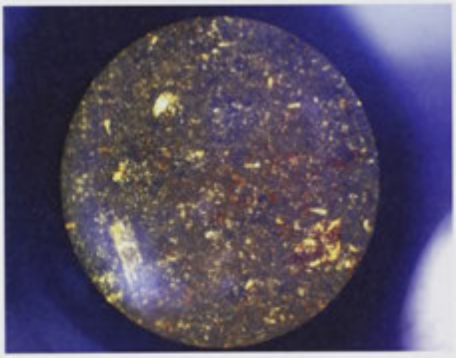


Fig 2-5. Photo #223.

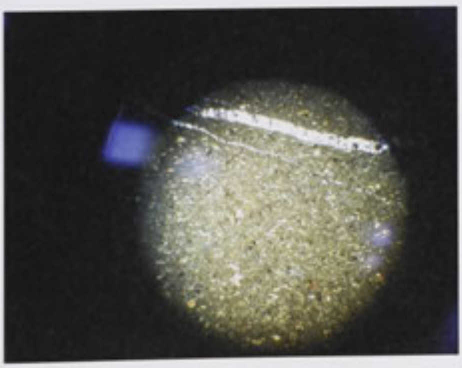


Fig 2-6. Photo #224.

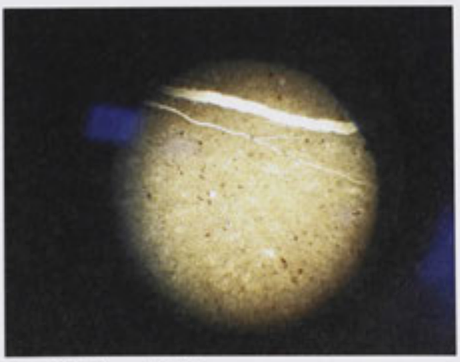


Fig 2-7. Photo #227.

Cat. No. 152:2

A similarly amorphous very fine grained rock to Cat. No. 160:1 with vein fills that are less distinct and clear. The grain size under higher magnification appears even finer than Cat. No. 160:1 and more consistent in size with regular packing. Banding visible by eye on the thin section is not clearly related to grain size change as in Cat. No. 160:1.

At one end of the thin section there is an unusual area where some form of alteration of the original texture has taken place to produce an irregular and irregularly bounded patch with less or no granular texture.

Fig 2-8. Cat. No. 152:2

Table 2-2. Description of samples.

Photo#	Polarization	Size of image	Description
231	PP	4 mm	A general view of the thin section showing a thin vein, amorphous texture, few visible crystals and a colour banding with a lighter band running from top right to bottom left through the centre of the image.
237	XP	4 mm	In crossed polars the banding is shown by amount of brown alteration present in the rock. Small lath shaped plagioclase crystals are present.
240	PP	4 mm	Two different textures in the same thin section.
243	XP	1.5 mm	At higher magnification the thin section contains a brown alteration along grain boundaries. There are a few crystals of plagioclase visible while most of the rest of the thin section is amorphous.
250	PP	1.5 mm	An alteration texture with paler areas showing voids where material has been lost.
251	XP	1.5 mm	In crossed polars the image reveals a blotchy amorphous altered appearance with little identifiable material.

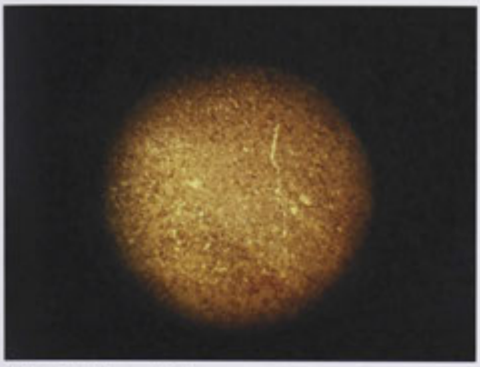


Fig 2-9. Photo#231.

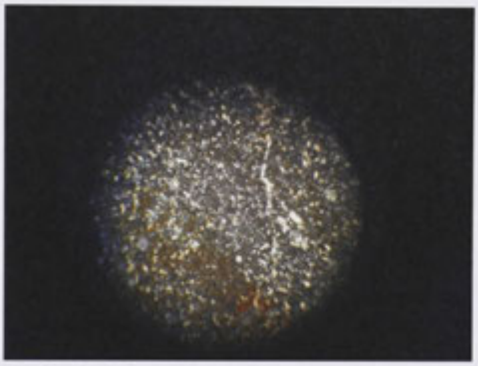


Fig 2-10. Photo#237.

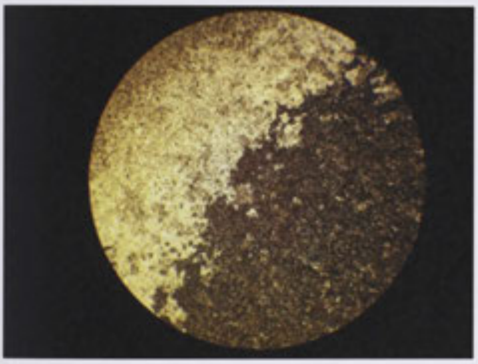


Fig 2-11. Photo#240.

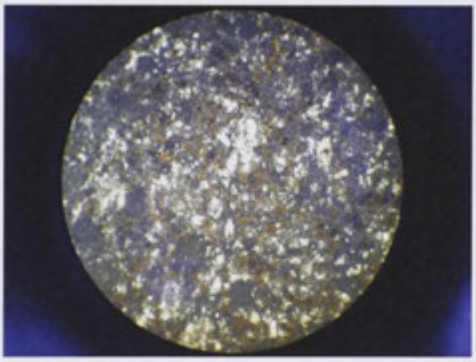


Fig 2-12. Photo#243.

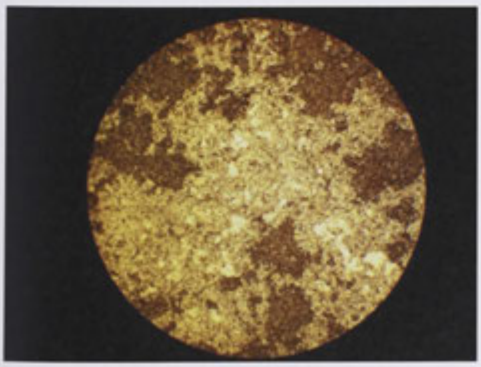


Fig 2-13. Photo#250.

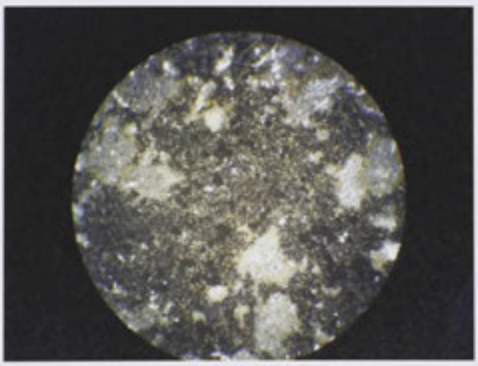


Fig 2-14. Photo#251.

Cat. No. 176:1

A similar very fine grained amorphous grey rock with veins to Cat. No. 160:1. A banding is visible on the thin section at low magnification composed of speckling with dark grains and colour. There are half a dozen clusters of dark opaque material surrounded by light haloes ~1 mm across.

At higher magnification the opaque mineral is a dark blue grey in some cases altered to a brown material. The pale haloes are reduction of the fine granular texture in the vicinity of these mineral aggregates. There are some grain size variations in the component fabric of the rock as in Cat. No. 160:1 but less distinctive.

Fig 2-15. Cat. No. 176:1.

Table 2-3. Description of samples.

Photo#	Polarization	Size of image	Description
254	PP	4 mm	Image showing amorphous fine grained nature of rock with thin veins crossing and opaque grains associated with the veins.
262	XP	4 mm	Under crossed polars differences in the groundmass are visible possibly reflecting presence of microcrystals.
263	XP	1 mm	Under high magnification a large opaque grain irregular in form with vein breaking crystal in two places. The surrounding groundmass shows some crystalline form but is still predominantly amorphous.
268	PP	1 mm	In plain light in the same area of the thin section the groundmass shows a granular texture.
269	PP	1.5 mm	Opaque grains associated with a vein showing alteration haloes. Groundmass fine granular to amorphous texture.
271	PP	1 mm	At higher magnification the opaque grains show irregular outlines and the groundmass a granular texture.
274	XP	1 mm	Under crossed polars the groundmass shows larger crystal forms (possibly plagioclase) Than the granularity visible in the plain light image. Brown staining relates to alteration.

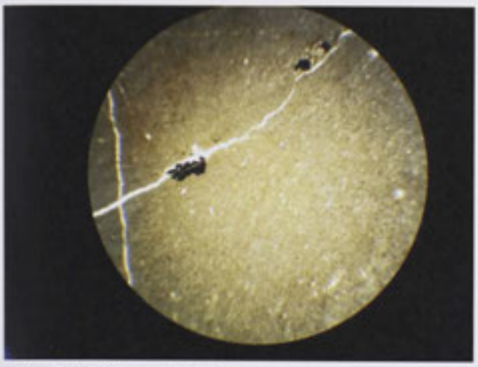


Fig 2-16. Photo# 254.

Fig 2-17. Photo# 262

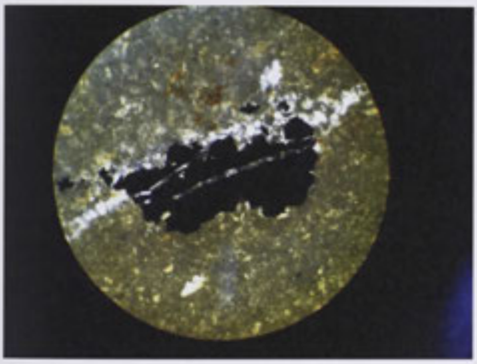


Fig 2-18. Photo# 263.

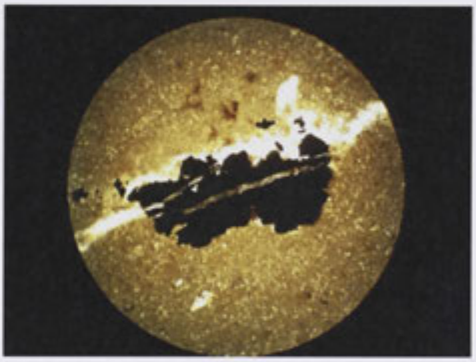


Fig 2-19. Photo# 268.

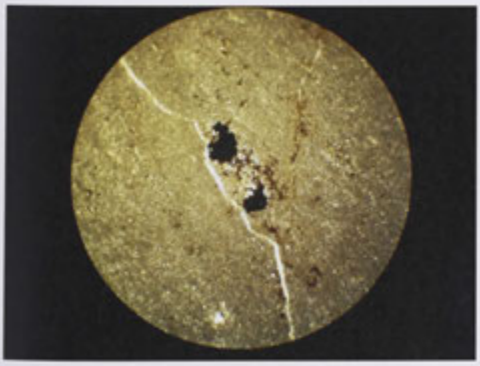


Fig 2-20. Photo#269

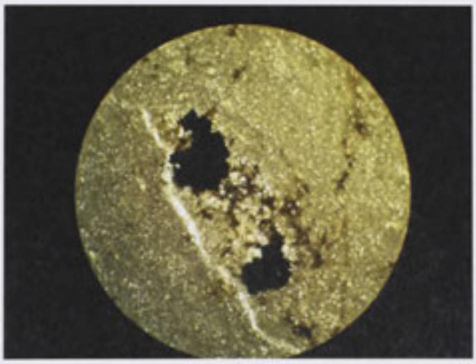


Fig 2-21. Photo#271

Cat. No. 161:1

A similar very fine grained amorphous grey rock to Cat. No. 160:1. At low magnifications and by eye a banding is visible in the thin section which relates to dark flecking and colour differences which possibly relates to grain size. Only one minor fracture with vein filling is visible.

There is a patch of reduced granular texture and colour in the same style as found in Cat. No. 152:2. The dark flecks are amorphous – they might possibly reflect alteration.

Fig 2-22. Cat. No. 161:1.

Table 2-4. Description of samples.

Photo#	Polarization	Size of image	Description
283	PP	4 mm	Image showing banding of specimen with very fine grain size and variation between bands.
285	XP	4 mm	Under crossed polars the same area shows differentiation into irregular zones resembling some form of growth of minerals.
287	PP	1.5 mm	View of vein crossing thin section with very fine granular texture of groundmass.
290	XP	1.5 mm	Patchy differentiation visible under crossed polars.

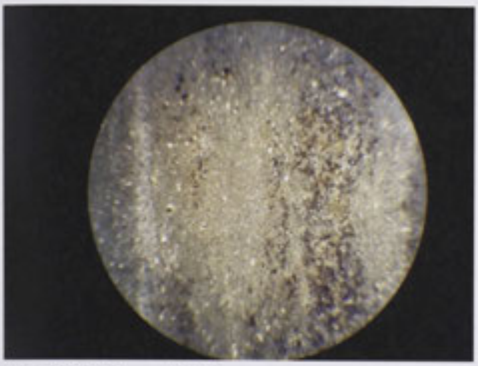


Fig 2-23. Photo# 283.

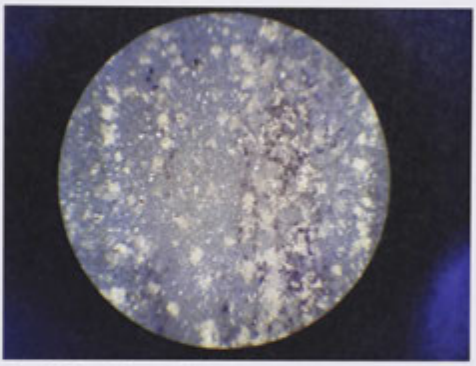


Fig 2-24. Photo# 285

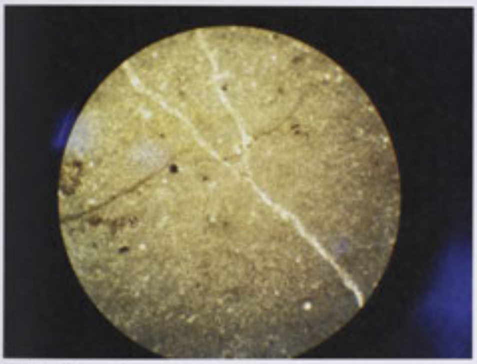


Fig 2-25. Photo# 287.

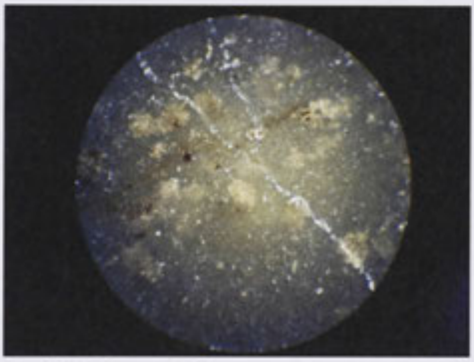


Fig 2-26. Photo# 290.

Cat. No. 175:1

A fine grained amorphous grey rock similar to Cat. No. 160:1 but with a heavier veining. The veins reach several mm thick crossing the specimen on an angle to the long axis in a subparallel anastomosing arrangement. The infill is almost monomineralic – possibly silica/quartz as it lacks cleavage is low relief. Crystals are up to 0.25 mm. There are rare small high relief grains visible within the veins. The rock shows variation in colour/shading. Some flecking with amorphous material as in Cat. No. 161:1.

At higher magnification the rock is composed of a regular arrangement of very fine even sized grains packed closely together. The veination resembles tension gashes with the vein fill forming short thin partings which comprise a significant proportion of the rock in those areas.

There are some other angular detrital grains of other mineralogy with higher relief found rarely through the thin section.

Fig 2-27. Cat. No. 175:1.

Table 2-5. Description of samples.

Photo#	Polarization	Size of image	Description
294	PP	4 mm	Image showing significant veins crossing thin section with opaque mineral flecked surrounding rock.
295	XP	4 mm	Under crossed polars the veins are composed of crystals (possibly quartz).
298	XP	4 mm	The view shows the vein material is more coarse grained in the centre with a fine grained margin.
303	XP	4 mm	This image shows fine veins cutting at various angles through an amorphous very fine grained groundmass.


Fig 2-28. Photo# 294.

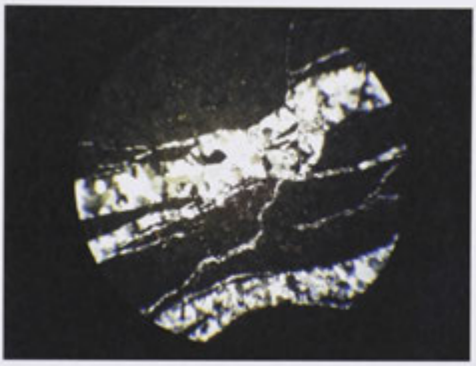


Fig 2-29. Photo# 295.

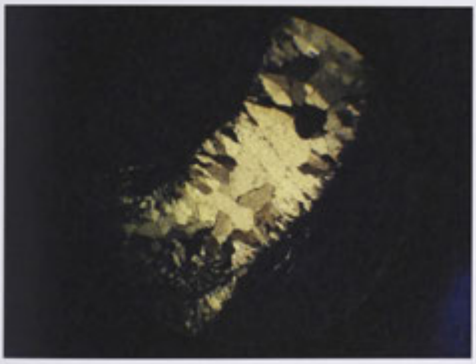


Fig 2-30. Photo# 298.

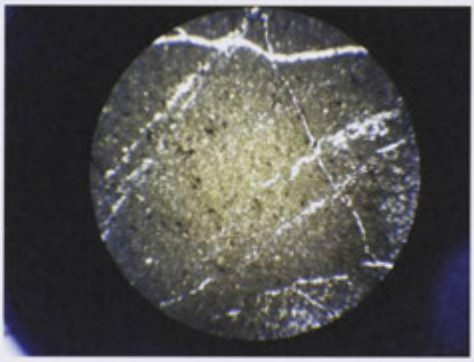


Fig 2-31. Photo# 303.

Cat. No. 151:3 (Section 1 & 2)

A similar fine grained rock to Cat. No. 160:1. This rock is paler in colour, mottled and more amorphous with the very fine grained closely packed texture being less distinct than Cat. No. 160:1 with a more widely spaced granularity separated by amorphous material with low relief and mottled appearance. Veination is also less well defined being paler and with less distinct margins. There is variation in colour and texture across specimen with darker areas having greater visible granularity than paler areas. The mottled appearance in plain light is composed of pale mottles 0.1-0.25 mm across which lack the fine granularity present elsewhere in the rock.

Such variation in texture and colour/shading may reflect weathering or alteration of the rock.

The specimen shows fine scale cracking parallel to the surface of artefact and extending up to 1 mm into the rock.

Fig 2-32. Cat. No. 151:3.

Table 2-6. Description of samples.

Photo#	Polarization	Size of image	Description
306	XP	4 mm	A vein crosses this image through a granular groundmass with probable plagioclase crystals.
310	XP	4 mm	Image showing two different types of vein/banding with coarse grained vein cutting at near right angles across a very fine grained wavy banding.
312	PP	4 mm	The image shows the nature of mottled areas of the thin section with little identifiable material. Fine grained opaque minerals are present.
314	XP	4 mm	Under crossed polars some microcrystals or a granular structure can be discerned.
322	PP	1.5 mm	At higher magnification variations in texture can be seen within the image.
323	XP	1.5 mm	Under crossed polars the granulation of the material is visible and a brown staining that is due to alteration from weathering.

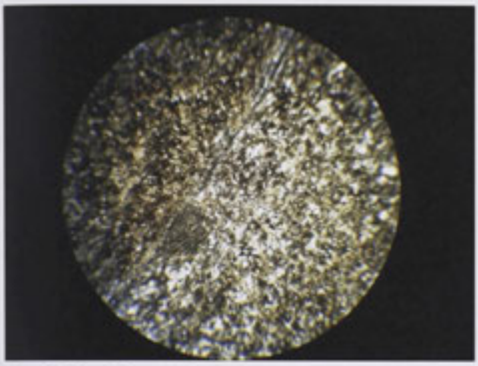


Fig 2-33. Photo# 306.

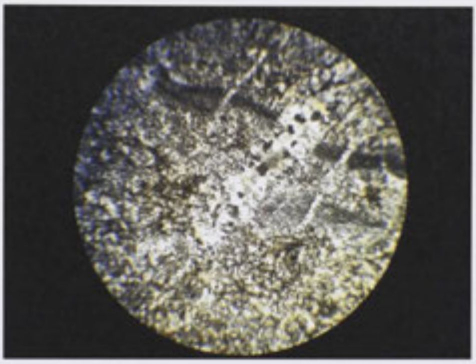


Fig 2-34. Photo# 310.

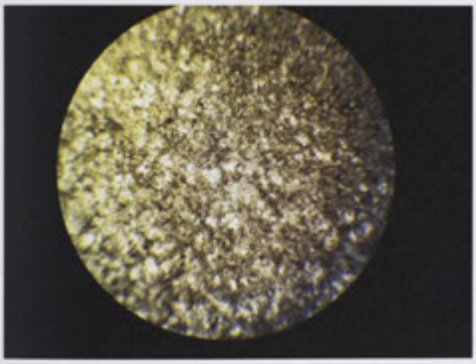


Fig 2-35. Photo# 312.

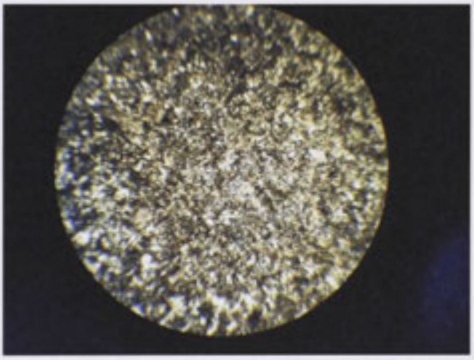


Fig 2-36. Photo# 314.

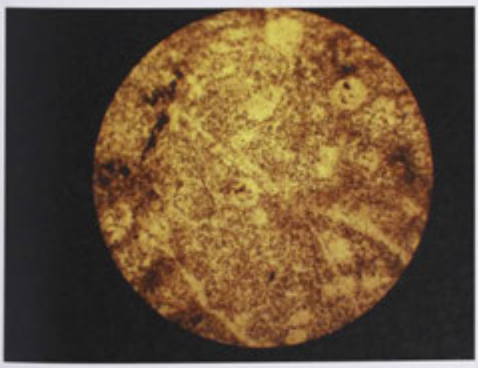


Fig 2-37. Photo# 322.

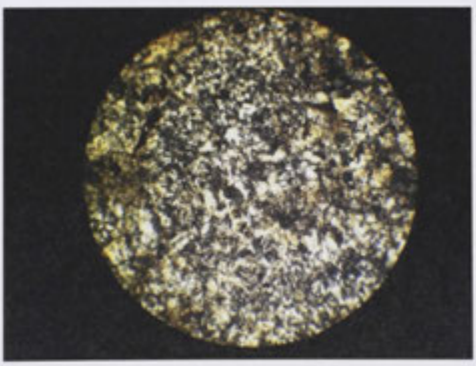


Fig 2-38. Photo# 323.

Dark volcanic fine grained

Cat. No. 9:6

A dark very fine grained amorphous rock with a scattering of visible crystal phenocrysts. Some colour variation suggestive of compositional or textural variation in a sub-linear fashion. At higher magnification the groundmass appears speckled as if a fine grained material. Larger crystals are predominantly <0.5 mm with one equidimensional aggregate cluster of several different minerals attaining 1 mm. These phenocrysts form 1-2% of the rock and show resorbed faces. Plagioclase and possibly[1] pyroxene are the probable minerals. Opaque mineral grains are also present.

Fig 2-39. Cat. No. 9:6.

Table 2-7. Description of samples.

Photo#	Polarization	Size of image	Description
329	XP	1.5 mm	Aggregate of plagioclase and pyroxene phenocrysts and smaller opaque minerals. The aggregate shows resorbed margins.
330	PP	1.5 mm	In PP the aggregate lies within a mottled amorphous material. The black opaque minerals are distinct and lie mostly along grain boundaries.
334	PP	4 mm	Image showing amorphous groundmass and rare phenocrysts.
335	XP	4 mm	Image showing rock composed dominantly by very fine grained amorphous groundmass with a few phenocrysts of plagioclase.

[1] Author's comment: Questionmarks (?), used to denote uncertain assesments, in the original analysis protocol have here and henceforth been substituted with either 'possible' or 'possibly'.

Fig 2-40. Photo# 329.

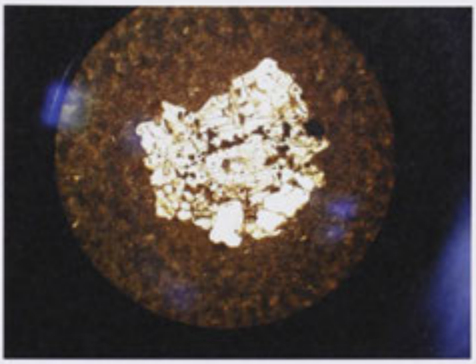


Fig 2-41. Photo# 330

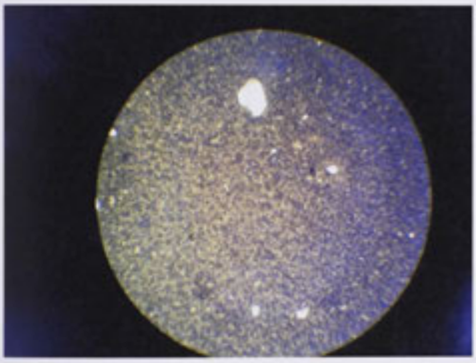


Fig 2-42. Photo# 334.

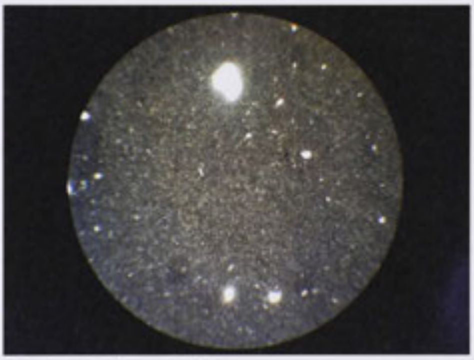


Fig 2-43. Photo# 335.

Cat. No. 16:1

A dark very fine grained mostly amorphous rock showing colour patterning – possibly flow banding. Microcrystals form a parallel to subparallel alignment of long axes. Larger crystals (0.5-1 mm) exhibit a similar alignment. The thin section shows a scattered mottling of small areas <0.5 mm.

At higher magnification there are two larger rounded oval shaped bodies which are lithic fragments composed of more aligned and more closely packed plagioclase microcrystals with minor ferromagnesium minerals. The microcrystals are needle shaped and very fine forming 20% of the rock. The mottling does not seem to relate to compositional or textural differences in the rock.

Phenocrysts form only 1-2% of the rock and exhibit resorbed faces: Plagioclase; Pyroxene – heavily altered; A hexagonal, clear, low birefringent mineral; Opaque mineral grains.

Fig 2-44. Cat. No. 16:1.

Table 2-8. Description of samples.

Photo#	Polarization	Size of image	Description
347	PP	4 mm	Fine grained groundmass with needle shaped microcrystals of plagioclase showing some alignment in a mottled amorphous material.
349	XP	4 mm	Fine grained groundmass with needle shaped microcrystals of plagioclase showing some alignment in a mottled amorphous material.
354	XP	4 mm	A possible lithic fragment in centre of image. Note dark banding running from top to bottom of image on right side.
361	XP	1.5 mm	At higher magnification the plagioclase needles in the groundmass show some alignment. A cluster of crystals with sharp faces is present.
364	XP	1.5 mm	A small cluster of high birefringence minerals near the edge of the specimen within the microcrystalline plagioclase, fine black opaque minerals and amorphous material groundmass.

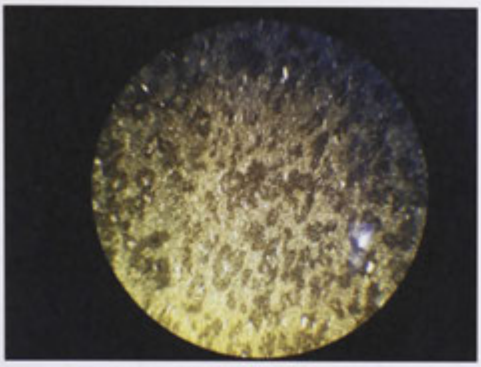


Fig 2-45. Photo# 347.

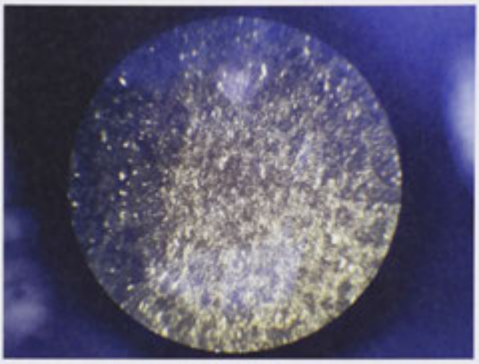


Fig 2-46. Photo# 349.

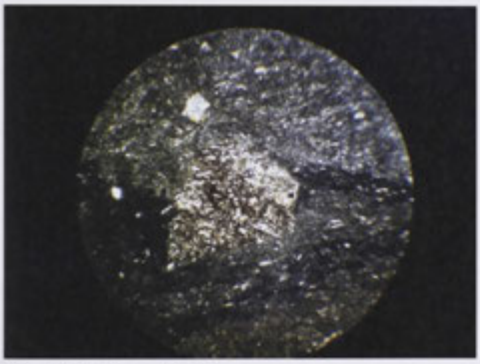


Fig 2-47. Photo# 354.

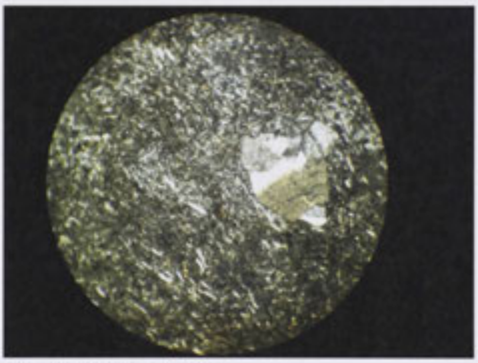


Fig 2-48. Photo# 361.

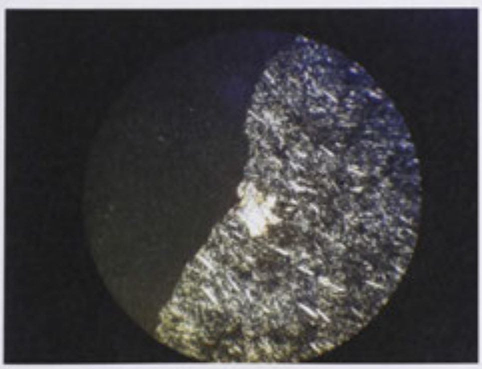


Fig 2-49. Photo# 364.

Cat. No. 26:1

An amorphous or very fine grained grey volcanic rock with similar but larger mottling to Cat. No. 16:1. At higher magnification small opaque mineral grains can be seen scattered through the rock (5%). A subtle 'lost' lath to needle shaped crystal texture is apparent underlying the now more amorphous texture of the majority of the rock. There are only a handful of visible crystal grains – showing good to resorbed faces. An unusual mineral hexagonal, low relief, low-moderate birefringence with a cleavage plain on rectangular sections and possible 90 degree on hexagonal face.

The mottling that is distinct in a hand examination of the thin section is made up of >1 mm paler areas set in an irregular darker network/grid. No significant mineralogical or texture difference visible in thin section.

Fig 2-50. Cat. No. 26:1.

Table 2-9. Description of samples.

Photo#	Polarization	Size of image	Description
368	PP	4 mm	A general view of the thin section showing the mottled amorphous texture of much of the rock with a few small phenocrysts of plagioclase.
374	XP	4 mm	Under crossed polars there are very fine needle shaped plagioclase crystals forming part of the groundmass.
376	PP	1 mm	At higher magnification the groundmass shows finely scattered black opaque grains and other microcrystals.
384	XP	1 mm	A higher magnification view of a distinctive hexagonal shaped crystal.

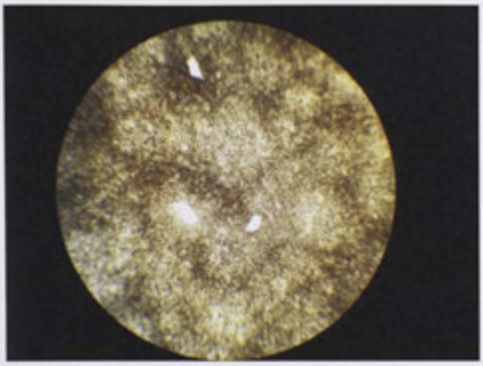


Fig 2-51. Photo# 368.

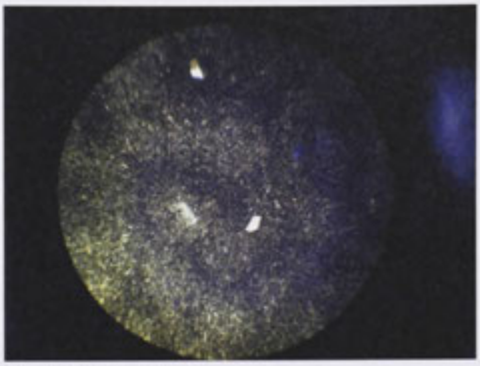


Fig 2-52. Photo# 374.

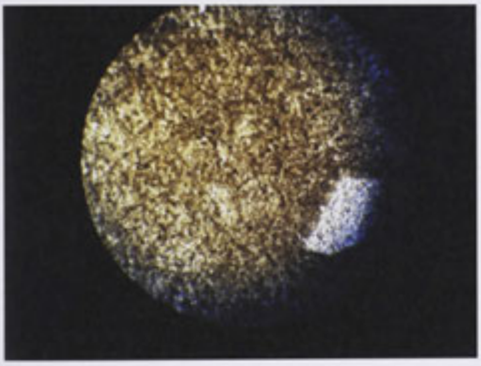


Fig 2-53. Photo# 376.

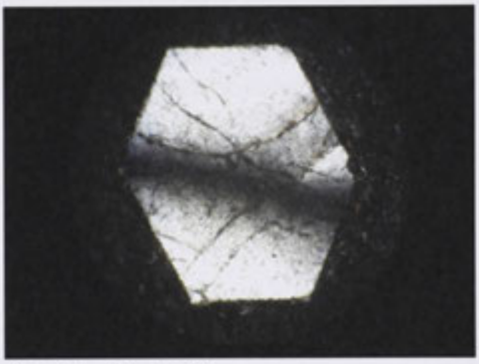


Fig 2-54. Photo# 384.

Cat. No. 64:1

A fine grained volcanic rock with microcrystals in darker amorphous groundmass. The crystals show no particular orientation. At higher magnification there are definite flow patterns and alignment of crystals. All crystals are </= to 1 mm and the majority <0.25-0.5 mm. Small to medium sized crystals are dominated by plagioclase in lath to needle form. Crystalline material is ~≤40% with slightly coarser (0.1-0.3 mm) more tabular plagioclase 10-20% of the rock.

Larger phenocrysts (>0.5 mm) form 1-2% of the thin section. There is an aggregate ~2 mm across of plagioclase, opaque mineral and pyroxene. Pyroxene and opaque mineral grains are often in close association. Plagioclase crystals are tabular, resorbed and grainy. Ferromagnesium minerals – possibly pyroxene. Opaques occur as dark grey blue grains forming 1-2% of the thin section.

Fig 2-55. Cat. No. 64:1.

Table 2-10. Description of samples.

Photo#	Polarization	Size of image	Description
385	PP	4 mm	Image showing mix of plagioclase crystals as lath or needle shaped with amorphous groundmass. A few black opaque mineral grains are present.
389	XP	4 mm	Under cross polars there are pyroxene crystals which are more equigranular and with higher birefringence than the plagioclase. There is some alignment to the plagioclase crystals.
392	XP	1.5 mm	At higher magnification the image is centred on a pyroxene crystal with a smaller plagioclase crystal cutting across it. The groundmass is seen to be plagioclase crystals within a dark material.

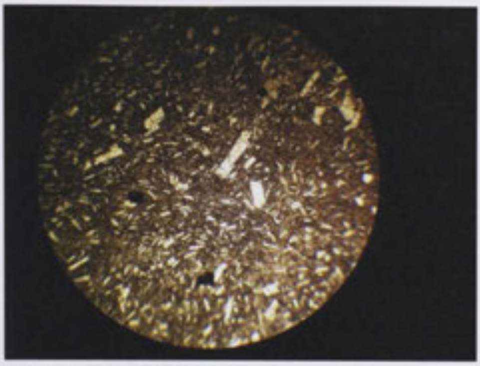


Fig 2-56. Photo# 385.

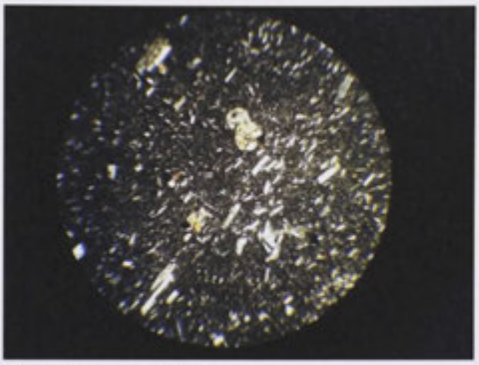


Fig 2-57. Photo# 389.

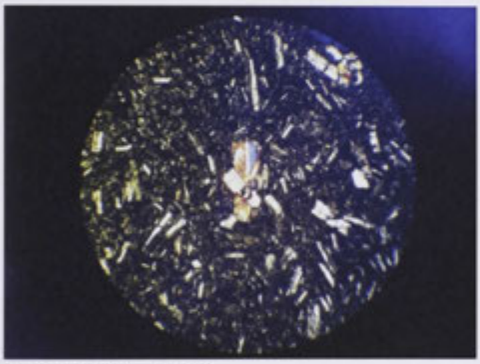


Fig 2-58. Photo# 392.

Cat. No. 136:5

A dark fine grained mottled volcanic rock. Two types of shading are visible – a darker scattered mottling of irregular equidimensional to elongate shaped areas usually <1 mm distributed fairly evenly across thin section comprising ~5% of the rock and a second generally fainter variation in shading of elongate broader areas that forms an alignment roughly parallel to the long axis of the specimen. In places the second shading matches the dark grey mottling (an area ~5 mm long). The darker areas of the thin section show non-linear flexing - possibly flow texture. Larger crystals are uncommon (1%).

Under higher magnification the rock is resolved as very fine grained with microcrystalline needles visible ≤0.1 mm in parallel to subparallel alignment set in a very finely granular groundmass that is flecked with minute opaque mineral grains. The needles seem most abundant at highest magnification (possibly 30%). The darker areas of mottling show no obvious difference in texture/composition to the surrounding material.

Fig 2-59. Cat. No. 136:5.

Phenocrysts up to 0.5 mm are mostly plagioclase showing resorbed faces. There are a few ferromagnesium mineral grains of brownish colour, high relief and birefringence. Opaque mineral grains are rare.

Table 2-11. Description of samples.

Photo#	Polarization	Size of image	Description
396	PP	4 mm	This image shows the rock has a mottled banding cutting nearly vertically along with a scatter of spots and rarer plagioclase phenocrysts of small size.
400	XP	4 mm	Under crossed polars there is little more visible.
403	XP	1.5 mm	Under higher magnification the groundmass shows very fine needles of plagioclase arranged in a subparallel alignment. The darker speckles are possibly a weathering feature.

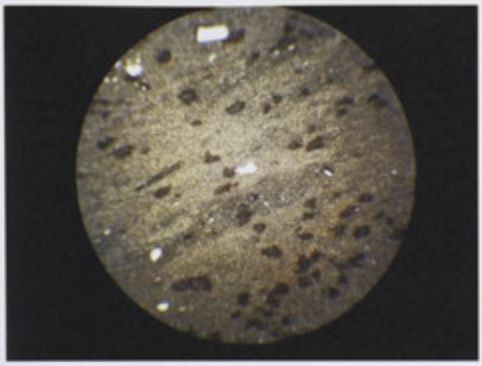


Fig 2-60. Photo# 396.

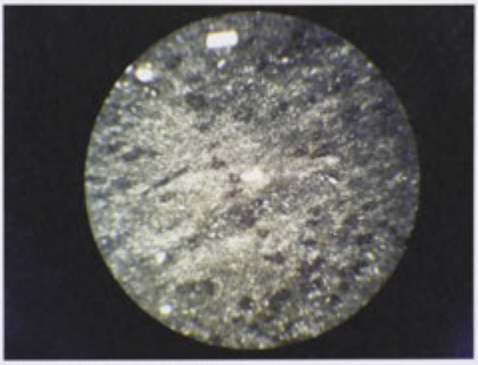


Fig 2-61. Photo# 400.

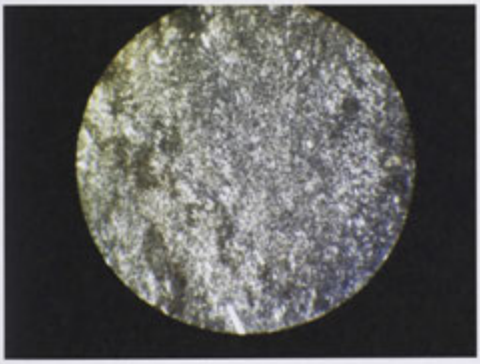


Fig 2-62. Photo# 403.

Cat. No. 154:18

A microcrystalline volcanic rock with minor phenocrysts. Needle like microcrystals show a patchy alignment of long axes and are larger and more abundant than in Cat. No. 136:5, forming the bulk of the rock perhaps as high as 60-70%. Plagioclase needles are dominant in this as needles <0.25 mm with the majority ~0.1 mm. A fine scattering of opaque mineral grains <0.05 mm forms 5% of the rock. There is not much amorphous material visible between the needle and lath shaped microcrystals.

Phenocrysts <0.75 mm form 1% of rock and include plagioclase and pyroxene crystals are grainy, zoned extinction with semi clean faces or resorbed.

Fig 2-63. Cat. No. 154:18

Table 2-12. Description of samples.

Photo#	Polarization	Size of image	Description
406	XP	4 mm	The image shows this rock is very fine grained with needles of plagioclase in an amorphous groundmass. There are very few larger crystals.
407	PP	1.5 mm	In plain light and higher magnification the plagioclase crystals show a random orientation. There are very fine black opaque grains present.
412	XP	1.5 mm	In crossed polars there is little additional detail.

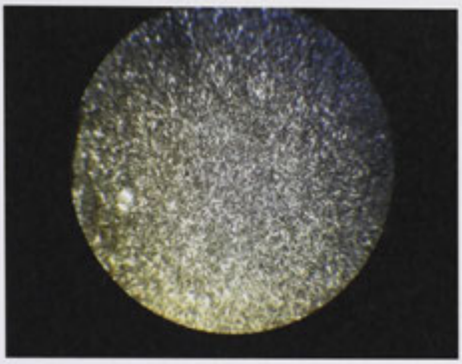


Fig 2-64. Photo# 406.

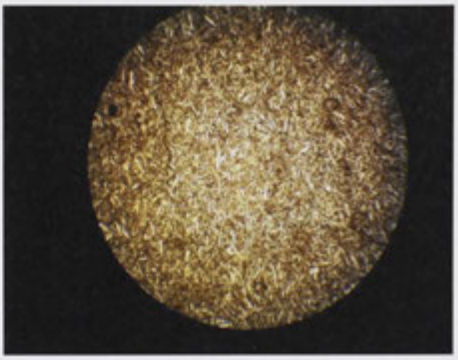


Fig 2-65. Photo# 407.

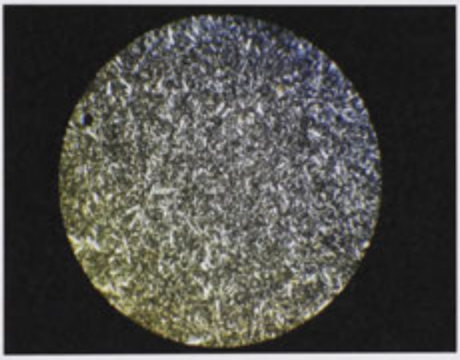


Fig 2-66. Photo# 412.

Cat. No. 163:2

A fine grained microcrystalline rock with little amorphous material. The rock is dotted with small brown coloured mineral grains forming rectangular to equidimensional forms within a matrix of subparallel to interlocking laths and needles of plagioclase. An even finer grained opaque mineral grain is common scattered across specimen.

At higher magnification plagioclase laths and needles reaching 0.2 mm are abundant forming 40% of rock. Opaques are possibly 10% of the rock at <0.05 mm. The groundmass is granular and birefringent. The brown mineral grains are moderate relief, little visible birefringence, usually ≤0.1 mm but one ~0.2 mm – possibly the alteration of another mineral – possibly olivine (1-2%).

There is a significant proportion of ferromagnesium minerals – higher birefringence, relief, more equidimensional or tabular in form and reaching 0.25 mm but predominantly 0.1 mm (possibly 10-20%). Poor crystal faces. Possibly mica.

Fig 2-67. Cat. No. 163:2.

Table 2-13. Description of samples.

Thin section 1:

Photo#	Polarization	Size of image	Description
414	XP	1.5 mm	A distinctive rock with much higher pyroxene content than other thin sections. Groundmass is microcrystalline with needles of plagioclase and small black opaque mineral grains.
418	PP	1.5 mm	In plain light the even scatter of small black opaque minerals is clear along with the brown coloured high relief phenocrysts.
424	PP	1.5 mm	A similar view with distinct brown mineral phenocrysts, plagioclase needles and groundmass. There is some alignment of the plagioclase needles at an angle to horizontal on the image.

Thin section 2:

Photo#	Polarization	Size of image	Description
425	XP	1.5 mm	Under crossed polars the abundant high birefringence (colourful) crystals of pyroxene stand out.

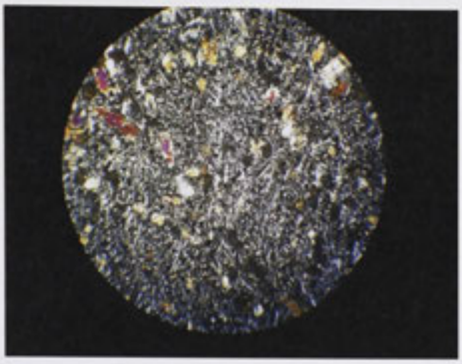


Fig 2-68. Photo# 414.

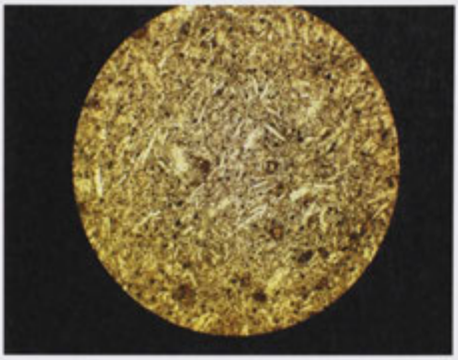


Fig 2-69. Photo# 418.

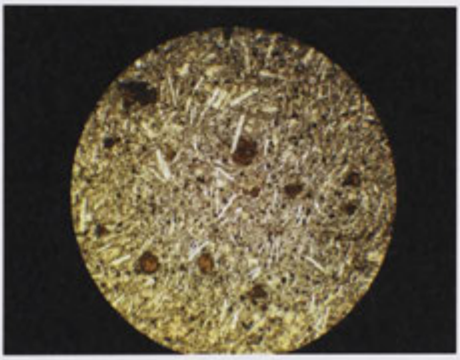


Fig 2-70. Photo# 424.

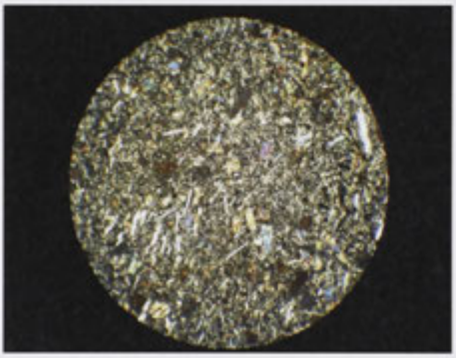


Fig 2-71. Photo# 425.

Cat. No. 166:3

A dark mottled very fine grained volcanic rock with very similar appearance to Cat. No. 136:5. The pattern of shading in the thin section reveals a possible flow texture roughly aligned with the long axis of the specimen. There is mottling which is similar in scale and abundance to Cat. No. 136:5 but here the mottling is less randomly distributed with a linear alignment or grouping of some of the mottles so that there are areas of higher and lower mottle abundance.

Microcrystalline material is similar to Cat. No. 136:5 in being fine needles scattered thinly and showing alignment with long axis. At a higher magnification the microcrystal needles reach 20-30% of the thin section while at intermediate magnification the rock is dominated by dark microgranular amorphous with needles 10-20%. Overall the groundmass is much more amorphous than seen in Cat. No. 154:18 or 136:5.

Phenocrysts form 1-2% of the thin section and crystal grains reach 1.5 mm and show grainy interiors and fairly clean crystal forms and faces. Most are <0.5 mm and dominated by: Plagioclase with one cluster or knot of 0.75 mm; Opaque mineral grains; Clinopyroxene crystals <0.5 mm.

Fig 2-72. Cat. No. 166:3.

Table 2-14. Description of samples.

Photo#	Polarization	Size of image	Description
432	PP	1.5 mm	Under moderate magnification the image shows this rock is composed of a very fine grained groundmass containing microcrystals and a few rare phenocrysts. There is a patchy spotting or mottling of the groundmass.
437	XP	1.5 mm	With crossed polars the groundmass shows very fine plagioclase crystals at different densities.
439	XP	1.5 mm	A cluster of pyroxenes within the groundmass.
447	XP	4 mm	Plagioclase and pyroxene phenocrysts in the groundmass.

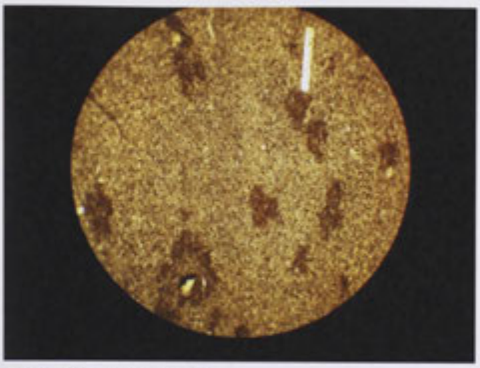


Fig 2-73. Photo# 432.

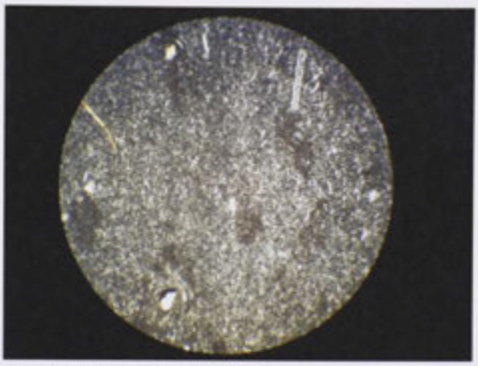


Fig 2-74. Photo# 437.

Cat. No. 171:2

A dark mottled very fine grained volcanic rock similar to Cat. No. 136:5 and 166:3. The mottling shows greater size variation with a smaller (~0.5 mm) mottle more common than in other thin sections. The mottles like in Cat. No. 166:3 show a tendency to form linear arrangements and to be elongated along that alignment.

The microcrystalline needles are similar in alignment and relative abundance to Cat. No. 136:5 and so is the microgranular appearing amorphous groundmass. There is variation in shading at a millimetre scale quite visible at higher magnification – dark bands or stripes 0.5 mm wide and stretching >4 mm contain more dark amorphous material than the average of the thin section.

Phenocrysts are present at 1-2% of the thin section and attain 2 mm in length: Plagioclase (and possibly K-feldspar) dominate and form tabular crystals with some inclusions; clinopyroxene in good condition as euhedral crystal <0.5 mm; opaque mineral grains.

Fig 2-75. Cat. No. 171:2.

Table 2-15. Description of samples.

Photo#	Polarization	Size of image	Description
450	PP	1.5 mm	Image shows the rock is composed of a very fine grained mottled groundmass with small phenocrysts of plagioclase.
454	XP	1.5 mm	Under crossed polars the groundmass contains needle shaped plagioclase.
456	XP	1.5 mm	A cluster of phenocrysts including plagioclase, pyroxene (brown) and opaque minerals.

Fig 2-76. Photo# 450.

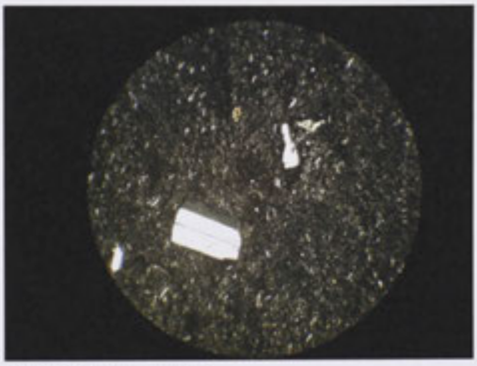


Fig 2-77. Photo# 454.

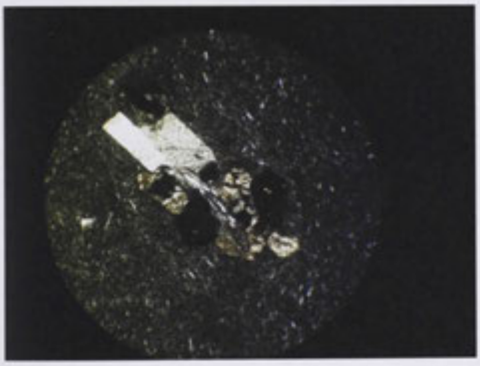


Fig 2-78. Photo# 456.

Cat. No. 172:1

A similar dark mottled microcrystalline volcanic rock to Cat. No. 136:5, 166:3 and 171:2. In this case the mottling has merged to form an interconnecting fabric that comprises >50% of the thin section. The mottling seems to occur as the intersection of two sets of parallel planes at an oblique angle. The needle like microcrystalline plagioclase/possibly glass material is <0.1 mm and shows subparallel alignment that varies greatly between areas of the thin section.

Phenocrysts are smaller in maximum size than in the other thin sections (<1 mm) but still represent 1-2% of the thin section: Plagioclase dominates; Pyroxene or possibly clino crystals show inclusions and good crystal form; opaque mineral grains; olivine crystal, possibly 0.2 mm; There is a 0.75 mm lithic fragment of coarser interlocking plagioclase crystals with dark shadowed margins.

Fig 2-79. Cat. No. 172:1.

Table 2-16. Description of samples.

Photo#	Polarization	Size of image	Description
460	PP	4 mm	This image shows the interconnecting mottles and very fine groundmass with rare small phenocrysts.
462	PP	1.5 mm	At higher magnification the groundmass can be seen to contain needle shaped plagioclase crystals aligned on a similar axis to the pattern of mottling.
474	XP	1 mm	At a higher magnification a pyroxene phenocryst with scattered very fine grained opaque minerals in the groundmass which contains needle shaped plagioclase and amorphous material.
465	XP	1.5 mm	This image shows the alignment of plagioclase needles in the groundmass matching that of the plagioclase phenocryst. There is irregular colour variation defined by abundance of microcrystalline material.

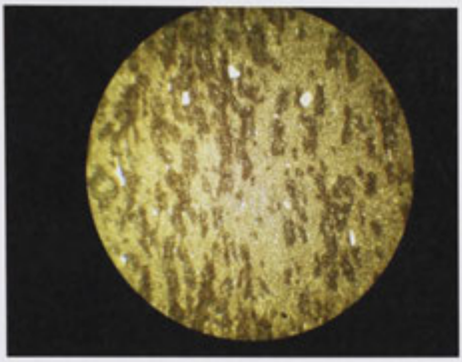


Fig 2-80. Photo# 460.

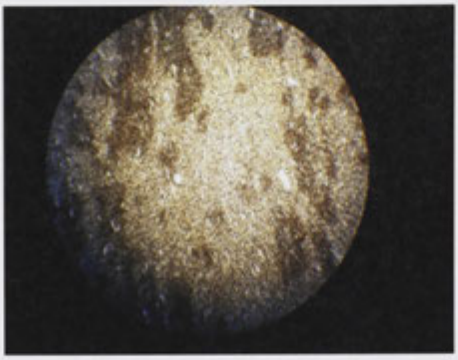


Fig 2-81. Photo# 462.

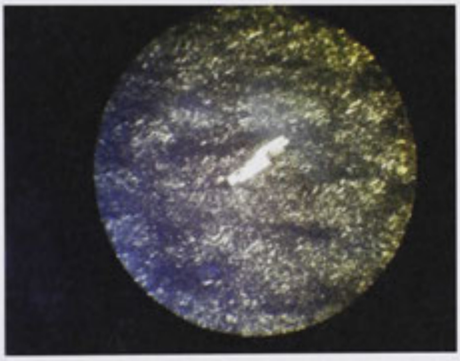


Fig 2-82. Photo# 465.

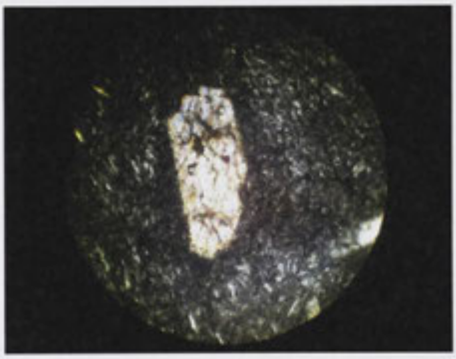


Fig 2-83. Photo# 474.

Light grey volcanic

Cat. No. 91:1

An igneous rock with porphyritic texture – large phenocrysts among smaller crystals set in amorphous grey groundmass. Phenocrysts often comprising clusters of individual crystal grains. An interesting 5 mm area contains a dark green coloured alteration along narrow radially arranged cracks.

The smaller sized tabular or equigranular crystals are <0.25 mm and poorly defined on their margins because of resorbtion. The better faceted crystals often possess dark cores. These smaller crystals form 20% of the rock and it is difficult to identify mineral varieties.

Phenocrysts forming 1-2% of the thin section reach 1.5 mm in length and clusters of individual crystal grains are common: Plagioclase with zoning and inclusions common.; Opaque mineral 1-2% mostly <<0.5 mm.

Fig 2-84. Cat. No. 91:1.

Table 2-17. Description of samples.

Photo#	Polarization	Size of image	Description
477	PP	4 mm	View of thin section in plain light showing scatter of small phenocrysts of plagioclase with resorbed margins set in amorphous groundmass with small opaque mineral grains (black).
479	XP	4 mm	In crossed polars the bright plagioclase pheoncrysts show up clearly against the dark grey of the groundmass.
483	XP	4 mm	A view in the centre and upper part of the image of green alteration along cavities or cracks in the rock. Two clusters of plagioclase phenocrysts are seen to the bottom of the image.
488	XP	1.5 mm	At a higher magnification the green alteration is distinctive. Some of the pale plagioclase crystals show etched faces and dark cores.

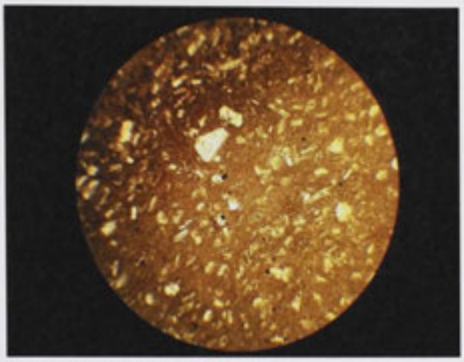


Fig 2-85. Photo# 477.

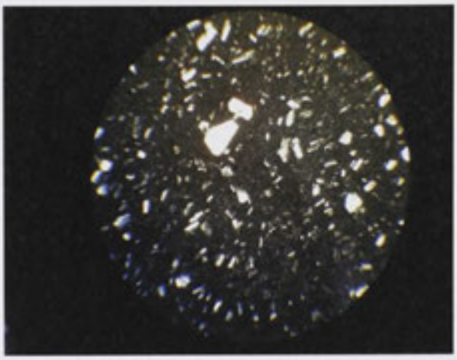


Fig 2-86. Photo# 479.

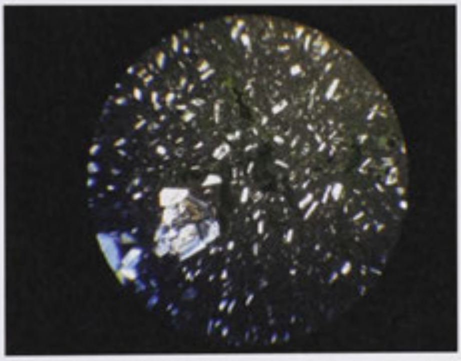


Fig 2-87. Photo# 483.

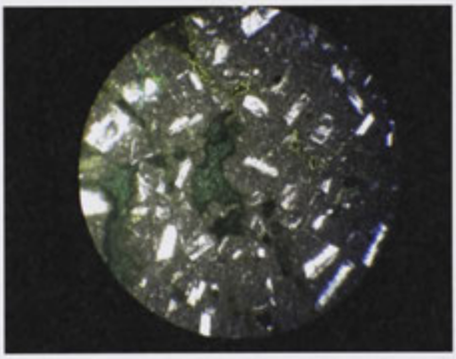


Fig 2-88. Photo# 488.

Cat. No. 97:4

A dark microcrystalline rock with phenocrysts. There is a brown orange discolouration and alteration across parts of the specimen particularly in the centre along visible cracks that are aligned along the long axis and close to the margins. Phenocrysts showing no particular orientation form 5% of the rock and attain 2 mm in length. Needle like microcrystals of plagioclase form the bulk of the rock (possibly ~50%). Opaque mineral grains are common as a fine grained scatter. There is an amorphous groundmass component.

At higher magnification the needle to lath like microcrystals of plagioclase are observed to form an interlocking to subparallel arrangement of 60% of the rock. The crystals are predominantly 0.1-0.25 mm long. Opaques form <5% of the rock as <0.1 mm grains.

Phenocrysts are dominated by: Plagioclase dominant as well formed crystals with slightly grainy interiors; possibly othropyroxene with good crystal shape and crystal faces not resorbed.

Fig 2-89. Cat. No. 97:4.

The brown material appears to be an alteration of the original plagioclase microcrystals and groundmass. It has a strong orange brown colour and higher relief but is not strongly birefringent. The material appears to alter the original crystal boundaries as it forms.

Table 2-18. Description of samples.

Photo#	Polarization	Size of image	Description
491	XP	1.5 mm	A lath shaped plagioclase crystal partly within a pyroxene crystal which also contains black opaque grains. These phenocrysts are set within a groundmass of plagioclase needles and opaque mineral grains and amorphous material.
494	XP	4 mm	In plain light the image shows the abundance of needle like plagioclase crystals making up the groundmass with a few scattered tabular plagioclase phenocrysts and less common brightly coloured plagioclase. The rock shows a brown discolouration from some form of alteration of the minerals and groundmass.
498	XP	1.5 mm	A plagioclase phenocryst with heavily resorbed faces and crystal growth within the crystal itself. The needle-lath shaped plagioclase crystals show a subparallel orientation from top left to bottom right.

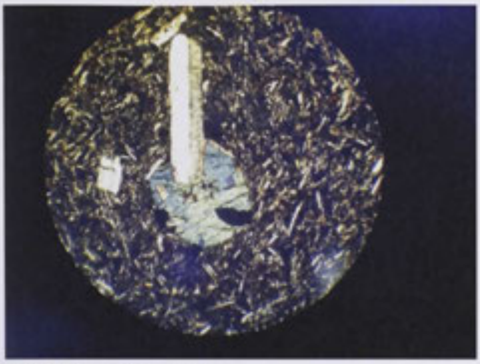


Fig 2-90. Photo# 491.

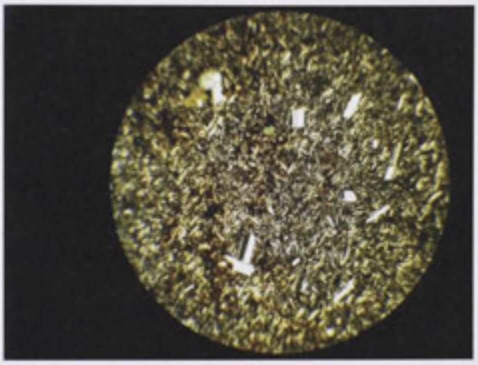


Fig 2-91. Photo# 494.

Fig 2-92. Photo# 498.

Cat. No. 97:3

A microcrystalline igneous rock with phenocrysts that resembles Cat. No. 91:1. A higher proportion of ferromagnesium minerals to plagioclase in the phenocrysts and many of these ferromagnesium grains show a loss of crystal material to leave voids. The phenocrysts are large and reach 5 mm.

Fine grained (<0.10 mm) opaque mineral grains are scattered through the rock (5%). The groundmass is microcrystalline and appears to be dominated by laths of plagioclase 0.1-0.25 mm long. This material is rather grainy and unclear including the grain boundaries.

Phenocrysts comprise 10-20% of the rock: possibly pyroxene and possibly clino dominates and a majority of the crystal grains are affected to some extent by loss of crystal material; plagioclase often zoned and with grainy interiors; possibly amphibole, a high birefringence, moderate relief and clear/colourless crystal.

There appears to be a number of ferromagnesium mineral types as some are brown coloured, some pale grey and some colourless. The larger brown coloured crystals are often missing much of their crystal content.

Fig 2-93. Cat. No. 97:3.

Table 2-19. Description of samples.

Photo#	Polarization	Size of image	Description
500	PP	4 mm	In plain light the image shows the rock is composed of a fine grained amorphous groundmass with an irregular distribution of phenocrysts concentrated in this image to the lower right.
503	PP	4 mm	In plain light the voids in the pyroxene and heavily altered mineral towards the top left of the image are clear.
507	XP	4 mm	A large pyroxene (brightly coloured) phenocryst with some loss of crystal material in core. In the upper part of the image a lenticular crystal has been altered heavily to leave an alteration product on margins and a void core.

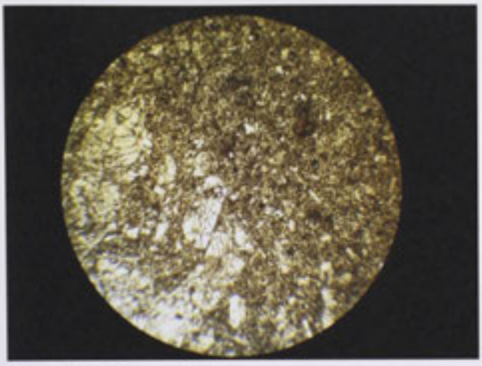


Fig 2-94. Photo# 500.

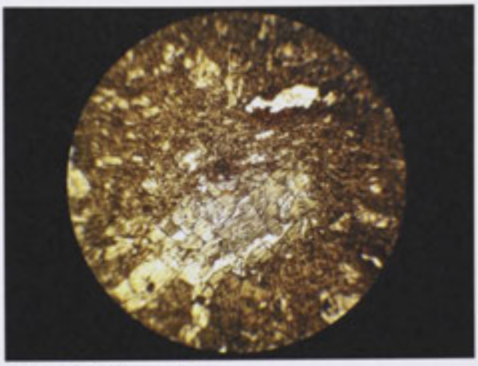


Fig 2-95. Photo# 503.

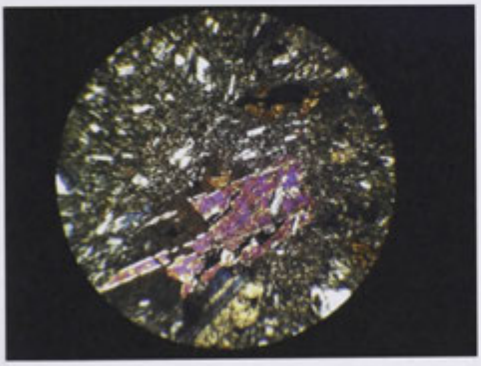


Fig 2-96. Photo# 507.

Cat. No. 99:1

A dark grey microcrystalline rock with occasional darker mottles and containing phenocrysts. Some very dark linear features run parallel to the long axis of the specimen and the needle like microcrystal content shows the same orientation. A 5x2.5 mm irregular (possibly glassy) ovoid object is black or clear (60% black) in both plain and cross polarised light. Microcrystalline plagioclase needles form 20% of the groundmass. Opaques form 1-2% of the rock with some larger grains attaining 0.25 mm associated with ferromagnesium clusters. Phenocrysts form 1-3% of the rock and reach 1 mm in length.

Plagioclase dominant as mostly clean faced and slightly grainy textured crystals.

Ferromagnesium minerals are present with high birefringence and cleavage.

The rock exhibits some cracks running along the long axis of the specimen.

Fig 2-97. Cat. No. 99:1.

Table 2-20. Description of samples.

Photo#	Polarization	Size of image	Description
508	XP	4 mm	An unusual object composed of a glassy low birefringent material.
511	XP	4 mm	Pyroxene and plagioclase phenocrysts.
515	XP	4 mm	An image showing some alignment of needle shaped plagioclase microcrystals scattered through the dark grey groundmass. A few larger plagioclase phenocrysts are present.

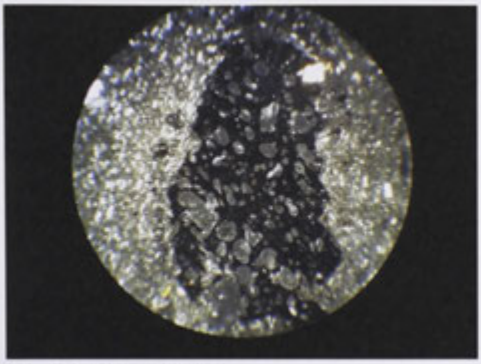


Fig 2-98. Photo# 508.

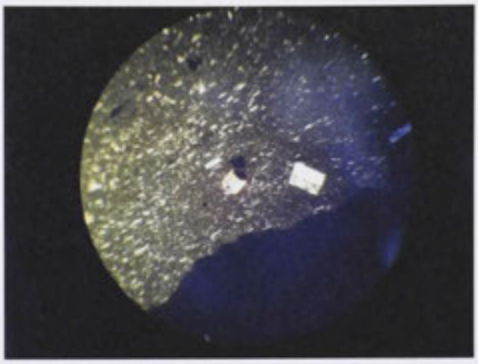


Fig 2-99. Photo# 511.

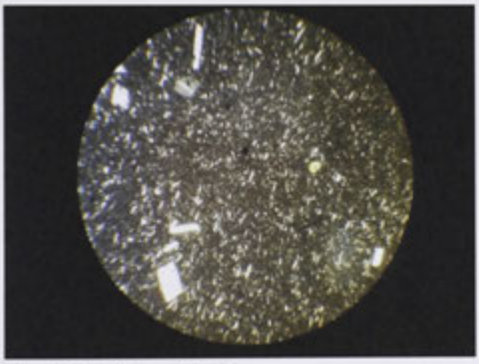


Fig 2-100. Photo# 515.

Cat. No. 132:3

A microcrystalline igneous rock with phenocrysts similar to Cat. No. 91:1 and 97:3. Very fine (<0.05 mm) opaque grains comprise 5% of the rock. The groundmass is composed of a birefringent somewhat amorphous material that appears microcrystalline though individual crystal grains are not distinctive.

Phenocrysts are common forming 20% of the rock but small at 0.5-1 mm:

Plagioclase dominant as tabular to equigranular forms – slightly grainy textured interiors, some zoned. Boundaries sharp to poorly distinct.

Ferromagnesium minerals are uncommon and show resorption/loss of crystal matter. There are a number of dark blue-grey or green altered grains <0.5 mm and one ferromagnesium mineral grain with similar material surrounding colourless crystal.

Fig 2-101. Cat. No. 132:3.

Table 2-21. Description of samples.

Photo#	Polarization	Size of image	Description
516	XP	4 mm	A clear image of the irregular plagioclase phenocrysts set in a groundmass of fine plagioclase crystals and amorphous dark grey material.
520	XP	1.5 mm	This image shows the groundmass composed of microcrystals of clear plagioclase needles or laths, small black opaque mineral grains and a grey to green amorphous material.
523	XP	1.5 mm	A phenocryst which has been heavily altered with a green coloured replacement material formed along the margins and interior fractures. A bright plagioclase phenocryst is at the top of the image.
527	PP	1.5 mm	In plain light the alteration mineral is distinct with a green colour compared with the clear original mineral. Small black opaque mineral grains are visible in the surrounding groundmass.

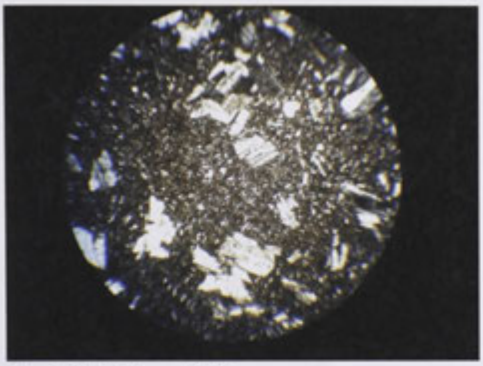


Fig 2-102. Photo# 516.

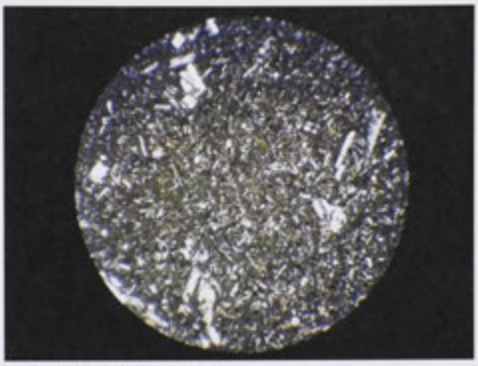


Fig 2-103. Photo# 520.

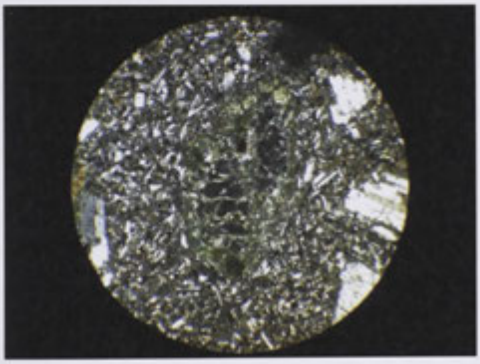


Fig 2-104. Photo# 523.

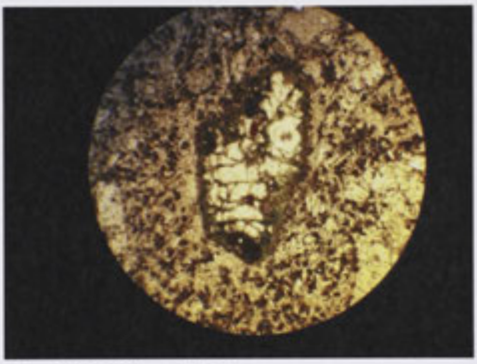


Fig 2-105. Photo# 527.

Coarse-grained igneous

Cat. No. 74:1

Porphyritic igneous rock with well formed phenocrysts set in a mottled grey groundmass. Groundmass being mottled contains embedded microcrystals in an otherwise amorphous material. Phenocrysts range from less than 0.5 mm up to 5 mm in length and form 20-30 percent of the rock. There is some brown discolouration around grains

Plagioclase is dominant (70% of phenocrysts) as square to tabular forms up to 3 mm with grainy interiors, resorbed faces and cracks. Often forms clusters.

Present ferromagnesium minerals: clinopyroxene, orthopyroxene, possibly hornblende, possibly olivine.

Opaque minerals with a dark blue grey black colour up to 0.5 mm in diameter are a minor component (1-2%).

Fig 2-106. Cat. No. 74:1.

Many of the ferromagnesium mineral grains show strong resorption with much of the crystal material removed and replaced by either a void or a low relief/birefringence material.

Table 2-22. Description of samples.

Photo#	Polarization	Size of image	Description
529	XP	4 mm	General view of thin section showing sharp bounded phenocrysts of plagioclase, more altered irregular phenocrysts of pyroxene (brown tinted in centre of image) and black opaque minerals set in dark grey amorphous groundmass. There is some brown alteration across thin section.
533	PP	4 mm	In plain light the amorphous nature of the groundmass is evident along with the brown alteration on the right of the image. The irregular margin of the rock on the thin section occurs on the lower left of the image.
3311	PP	4 mm	Another image showing the amorphous groundmass with scattered fine opaque mineral grains containing phenocrysts.
3314	XP	4 mm	A large blue coloured pyroxene phenocryst and smaller plagioclase crystals set in dark amorphous to micro-crystalline groundmass.
3315	XP	1.5 mm	A degraded pyroxene phenocryst showing alteration of crystal material and embedded crystals including an opaque mineral (black).

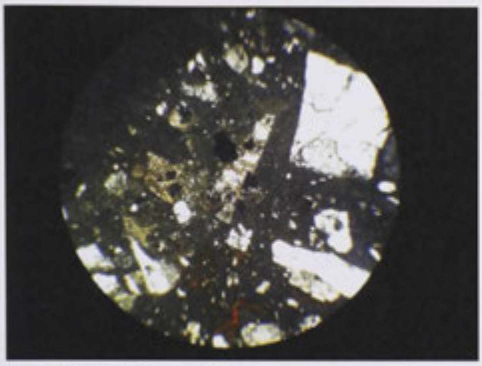


Fig 2-107. Photo# 529.

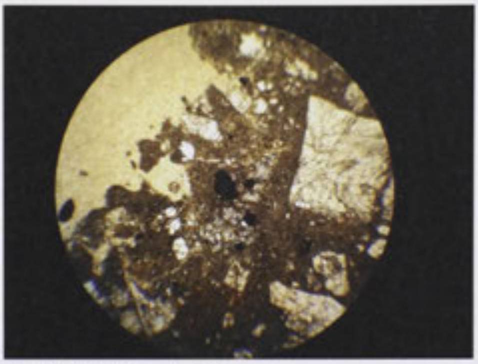


Fig 2-108. Photo# 533.

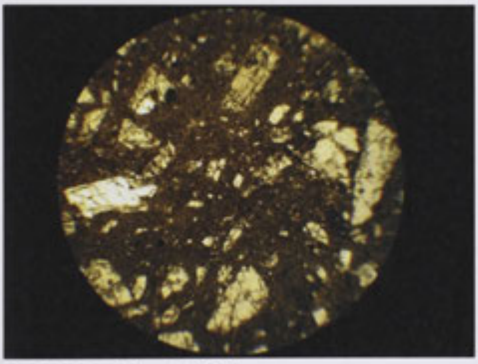


Fig 2-109. Photo# 3311.

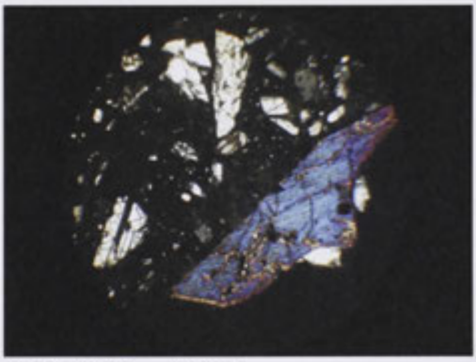


Fig 2-110. Photo# 3314.

Fig 2-111. Photo# 3315.

Cat. No. 18:7

Similar rock to Cat. No. 74:1 composed of phenocrysts (30%) up to 4 mm imbedded in an amorphous grey groundmass. At higher magnification some zones of the groundmass shows an interlocking microcrystalline texture. Fine grained opaque grains 5%.

Plagioclase crystals are grainy in appearance, sometimes zoned and many contain dark inclusions. Crystal form is more tabular and also some unusual forms.

Opaque mineral grains are common as more rounded and dark blue grey coloured forms up to 0.5 mm.

Ferromagnesium minerals form ≥20% of phenocrysts and show resorption of crystal material and in cases complete crystal replacement. Possibly pyroxene/amphibole – possibly hornblende.

Fig 2-112. Cat. No. 18:7.

Table 2-23. Description of samples.

Photo#	Polarization	Size of image	Description
3316	XP	4 mm	This image shows the presence of plagioclase (grey-white) and pyroxene (more brightly coloured) phenocrysts set in a microcrystalline to amorphous groundmass. Occasional large opaque minerals (black) are present.
3318	XP	1.5 mm	At higher magnification the groundmass can be seen to contain plagioclase crystals and opaque mineral grains. The brown colour is some form of alteration of the rock. The pale brown crystal left of centre is a pyroxene.
3320	PP	1.5 mm	In plane light the small black flecks of opaque minerals are seen scattered in the groundmass of the rock.

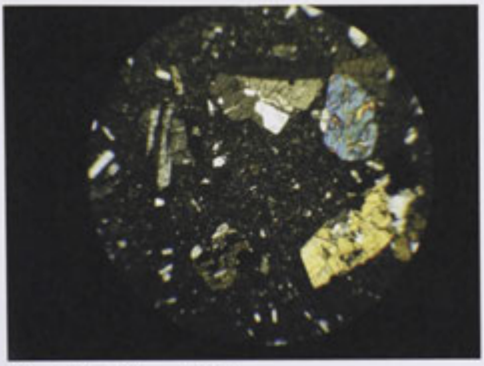


Fig 2-113. Photo# 3316.

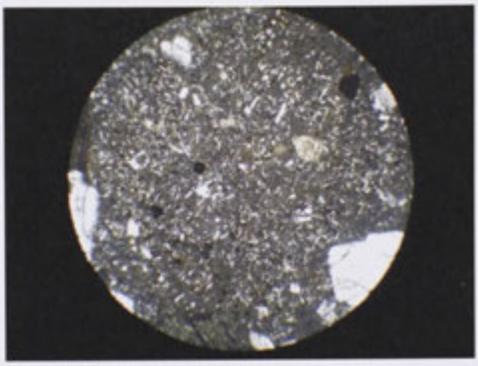


Fig 2-114. Photo# 3318.

Fig 2-115. Photo# 3320.

Cat. No. 153:1

Phencryst rich igneous rock with crystalline to amorphous fine grained groundmass. The phenocrysts are common and comprise in parts of the thin section more than 50% of the rock with individual grains reaching over 5 mm long. The rock is similar to Cat. No. 74:1 with perhaps a higher proportion of phenocrysts and the phenocrysts of larger size.

Plagioclase dominates phenocrysts with some aggregates of crystals. Crystal form tabular with a small ratio of long to short axes compared to other thin sections.

Pyroxenes – both clino and ortho forms. These (and possibly other) ferromagnesium minerals show considerable alteration/resorption of individual grains with loss of material; some almost entirely replaced. Original grain boundaries clear and crystal form was good.

Opaque mineral grains a minor component as larger grains but abundant as finer scattered grains (5%).

Fig 2-116. Cat. No. 153:1.

The groundmass is granular with tabular forms showing an alignment bending around phenocrysts. There is a brown coloured alteration along cracks in the rock composed of a cleaved ferromagnesium mineral (pyroxene/possibly hornblende).

Table 2-24. Description of samples.

Photo#	Polarization	Size of image	Description
3323	PP	4 mm	Large pyroxene phenocryst showing resorption/alteration of crystal.
3326	PP	4 mm	Large pyroxene phenocryst showing resorption/alteration of crystal and presence of opaque mineral grains.
3327	XP	4 mm	Under XP the same pyroxene crystal shows areas with loss of crystal material (dark grey) and other areas where alteration has produced new material (brown and without cleavage patterns).
3333	XP	4 mm	Image shows more tabular plagioclase crystals set in fine partly crystalline groundmass.

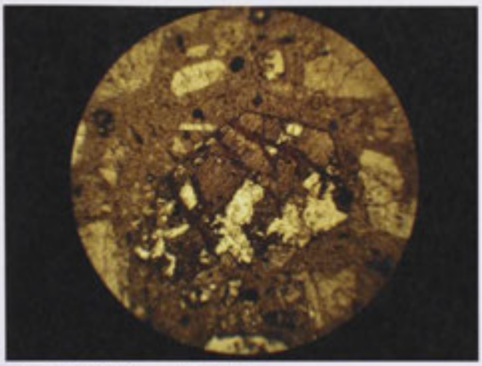


Fig 2-117. Photo# 3323.

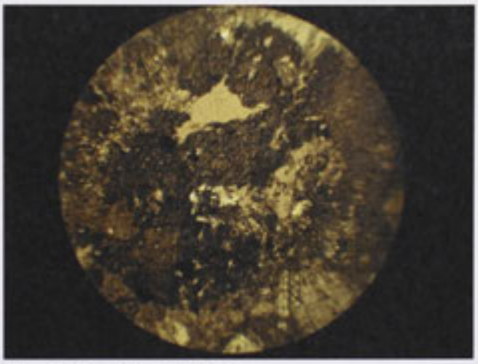


Fig 2-118. Photo# 3326.

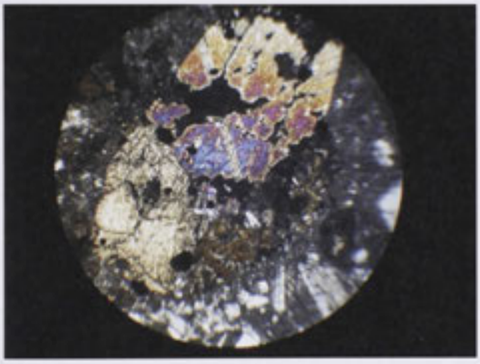


Fig 2-119. Photo# 3327.

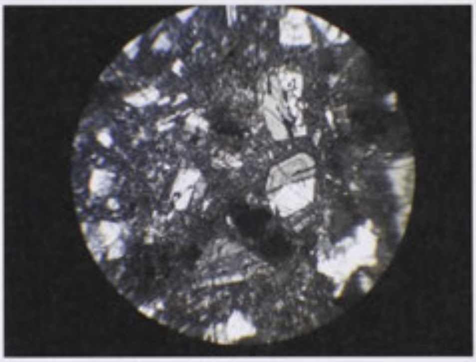


Fig 2-120. Photo# 3333.

Cat. No. 163:1.

A phenocryst rich igneous rock with a more crystalline groundmass than other coarse grained igneous specimens. Round vesicles 0.2-0.8 mm form 5% of the thin section. The groundmass composed of interlocking needles of plagioclase with scattered fine grains of opaque minerals (5%) with very little amorphous material. Melt not quenched as with other samples. Phenocryst content (20-30%) similar to other thin sections and a grainy appearance.

Plagioclase higher proportion of phenocrysts with grainy appearance, abundant opaque inclusions and crystals reaching 5 mm in length.

Ferromagnesium minerals mostly altered/resorbed to a low relief, birefringence (possibly void) matter with only traces of original mineral matter. Probably 2 pyroxenes.

Opaque minerals: Olivine – an occasional resorbed grain.

Fig 2-121. Cat. No. 163:1.

Table 2-25. Description of samples.

Photo#	Polarization	Size of image	Description
3335	XP	4 mm	Image shows phenocrysts of plagioclase surrounded by matrix composed of needle like plagioclase crystals and more equidimensional brown colour crystals.
3337	PP	4 mm	The plane light image shows the grainy nature of the thin section.
3342	XP	1 mm	A magnified view showing interlocking needle like plagioclase crystals forming groundmass. The dark grey patches are vesicles with the most distinctive on the lower right edge.
3345	XP		Olivine (bright blue crystal), pyroxene and plagioclase phenocrysts form interlocking groups on the left and bottom of the image. Surrounding them is the crystalline groundmass.

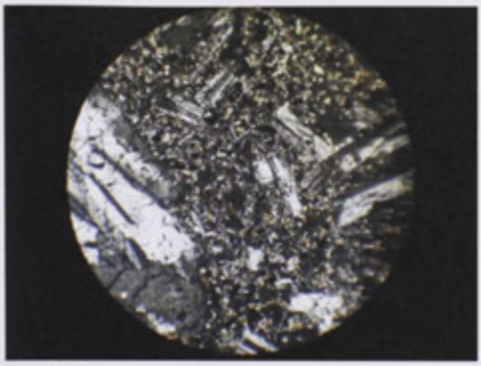


Fig 2-122. Photo# 3335.

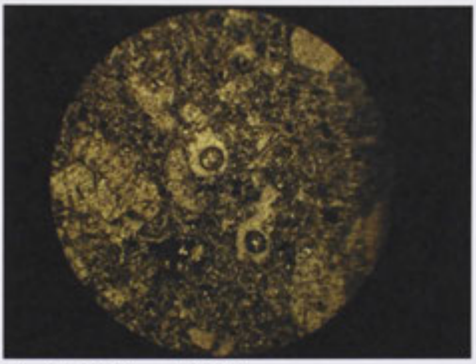


Fig 2-123. Photo# 3337.

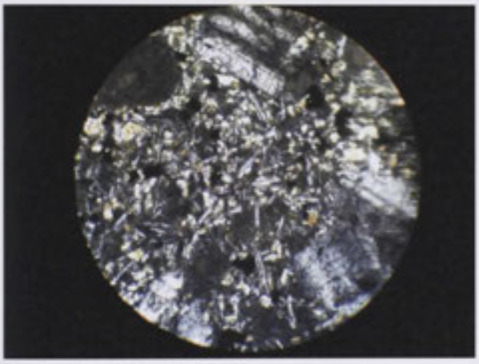


Fig 2-124. Photo# 3342.

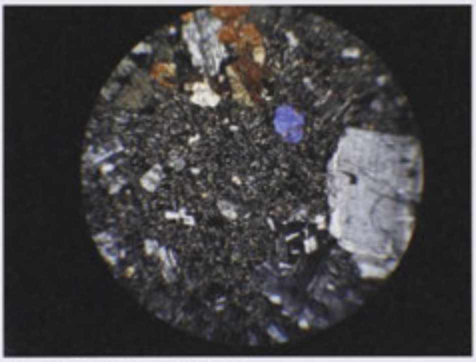


Fig 2-125. Photo# 3345.

Appendix 3:
Shell

Adzes

1:1

5:1

8:1

43:1

Scale 1:1

69:1

69:2

86:1

88:1

Scale 1:1

Chisels

94:1

1:2

92:1

Fish hooks

40:1

80:1

80:2

97:1

108:1

108:2

117:1

125:2

170:3

171:3

Scale 1:1

Worked urchin spine

102:1

131:2

170:2

171:1

73:1

77:1

92:3

150:1

Scale 1:1

Pendants – discs

156:1

132:1

156:3

74:1

157:3

Scale 1:1

Large rings/bracelets

122:2

131:1

65:1

151:1

155:6

91:1

169:1

Feature H:1

157:6

Scale 1:1

Rings – beads – discs

157:6

157:7

157:8

159:1

51:1

159:2

170:1

157:5

158:2

159:3

82:1

93:1

169:2

172:1

81:1

131:3

Scale 1:1

Cypraeidae

155:2

98:1

90:2

120:1

83:1

176:1

124:1

143:2

155:1

Scale 1:1

Perforated shell

155:8

157:2

153:1

28:1

64:1

89:1

90:1

Scale 1:1

Worked shell

110:1

122:1

160:1

142:1

100:1

143:1

158:1

Scale 1:1

11:1

141:1

28:2

105:1

114:1

114:2

125:1

155:3

157:1

171:2

Scale 1:1

List of finds

Cat. no.	Depth (cm)	Unit	Category	Family	Genus	Species	Comment	Photo
1:1	23-35	1	Adze	Tridacnidae	*Tridacna sp.*			x
1:2	20-35	1	Chisel	N/A	*Probably Tridacna*			x
1:3	23-35	1	Ring/bracelet (large)	Conidae	*Conus sp.*			
5:1	23-35	5	Adze	N/A			Fragment	x
8:1	23-35	8	Adze	Tridacnidae	*Tridacna*	maxima		x
11:1	35-50	2	Worked shell	N/A			Well weathered, worked bivalve	x
24:1	50-65	6	Disc	Conidae	*Conus sp.*		Perforation	
28:1	65-80	1	Worked shell	Pteriidae				x
28:2	65-80	1	Worked shell	Pteriidae	*Isognomon sp.*		Worked tree oyster shell, hinge visible, possible blank	x
38:1	80-90	2	Ring/bead (small)	Conidae	*Conus sp.*			
38:2	80-90	2	Ring/bead (small)	Conidae	*Conus sp.*			
39:1	80-90	3	Ring/bead (small)	Conidae	*Conus sp.*			
40:1	80-90	4	Fish hook	Pteriidae/ Trochidae				x
43:1	80-90	7	Adze	Tridacnidae	*Tridacna sp.*		Fragment	x
46:1	90-100	1	Bead (medium)	Conidae	*Conus*	litteratus		
48:1	90-100	3	Ring/bead (small)	Conidae	*Conus sp.*			
49:1	90-100	4	Ring/bead (small)	Conidae	*Conus sp.*			
51:1	90-100	6	Bead (medium)	Conidae	*Conus sp.*			x
55:1	100-110	1	Ring/bead (small)	Conidae	*Conus sp.*			
55:2	100-110	1	Adze	Tridacnidae	*Tridacna sp.*		Fragment	
59:1	100-110	5	Ring/bead (small)	Conidae	*Conus sp.*			
64:1	110-120	1	Worked shell	Pteriidae				x
65:1	110-120	2	Ring/bracelet (large)	Conidae	*Conus sp.*			x
67:1	110-120	4	Ring/bead (small)	Conidae	*Conus sp.*			
69:1	110-120	6	Adze	Tridacnidae	*Tridacna*	maxima		x
69:2	110-120	6	Adze	Tridacnidae	*Tridacna*	maxima		x
73:1	120-130	1	Abrader (poss.)	Urchin Spine			Distal tip	x
74:1	120-130	2	Disc	Conidae	*Conus sp.*		Perforation (central, small)	x
76:1	120-130	4	Adze	Tridacnidae	*Tridacna sp.*		Worn? Slug?	
77:1	120-130	5	Abrader (poss.)	Urchin Spine				x
80:1	120-130	8	Fish hook	Pteriidae/ Trochidae			J-shaped	x
80:2	120-130	8	Fish hook	Pteriidae/ Trochidae			J-shaped	x

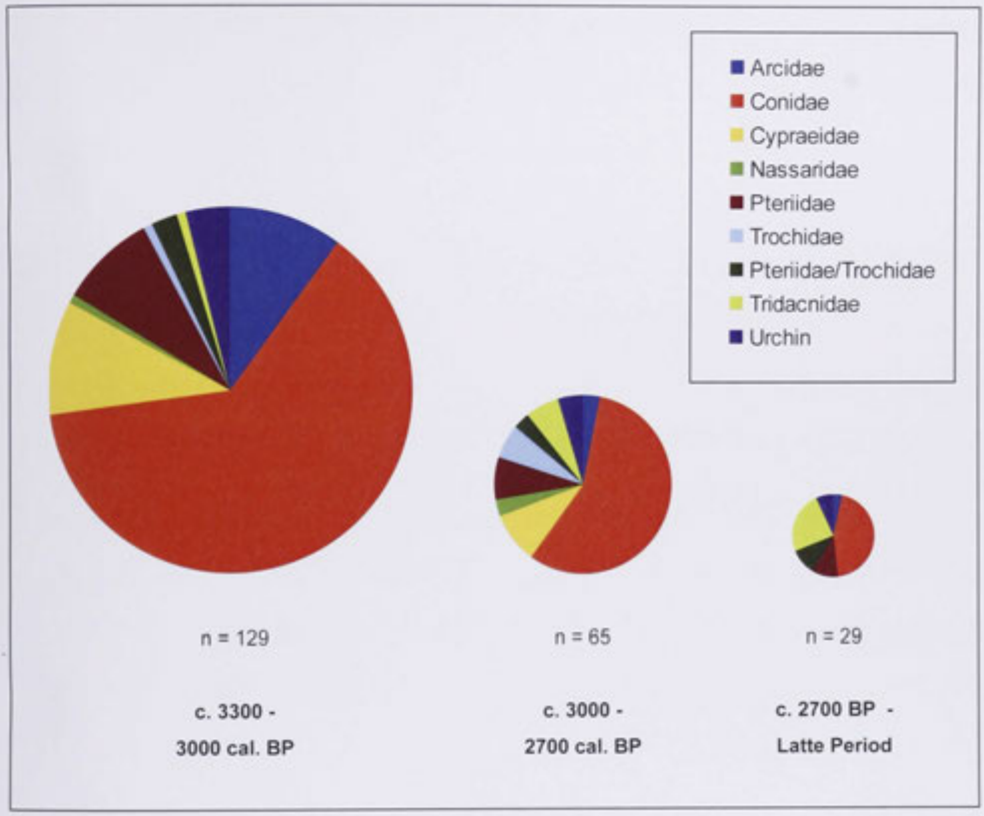
Cat. no.	Depth (cm)	Unit	Category	Family	Genus	Species	Comment	Photo
81:1	130-140	1	Disc	Conidae	*Conus sp.*		Perforation (incom-plete)	x
81:2	130-140	1	Worked shell	Tridacnidae	*Tridacna sp.*		Flaked	
82:1	130-140	2	Ring	Conidae	*Conus sp.*			x
83:1	130-140	3	Worked shell	Cypraeidae	*Cypraea sp.*		Dorsal surface re-moved	x
83:2	130-140	3	Abrader	Urchin Spine				
84:1	130-140	4	Worked shell	Trochidae	*Trochus sp.*		Perforation	
84:2	130-140	4	Disc	Conidae	*Conus sp.*		No perforation	
85:1	130-140	5	Ring/bead (small)	Conidae	*Conus sp.*			
86:1	130-140	6	Adze	Tridacnidae	*Tridacna*	maxima		x
88:1	130-140	8	Adze	Tridacnidae	*Tridacna*	maxima		x
88:2	130-140	8	Fish hook	N/A	*N/A*	N/A		
89:1	140-150	1	Worked shell	Pteriidae			Perforation, possible bead blank	x
90:1	140-150	2	Worked shell	Trochidae	*Trochus sp.*		Perforation, possible blank	x
90:2	140-150	2	Lure (poss.)	Cypraeidae	*Monetaria*	moneta	Dorsal surface re-moved	x
91:1	140-150	3	Ring/bracelet (large)	Conidae	*Conus sp.*		Two fragments	x
92:1	140-150	4	Chisel	Conidae	*Conus sp.*			x
92:2	140-150	4	Pendant	Cypraeidae			Dorsal surface with two perforations	x
92:3	140-150	4	Abrader (poss.)	Urchin Spine			Two fragments	x
92:4	140-150	4	Ring/bead (small)	Conidae	*Conus sp.*			
92:5	140-150	4	Ring/bead (small)	Conidae	*Conus sp.*			
93:1	140-150	5	Disc	Conidae	*Conus sp.*		Perforation (central)	x
94:1	140-150	6	Adze	Tridacnidae	*Tridacna*	maxima		x
94:2	140-150	6	Disc	Conidae	*Conus sp.*		Perforation (central, small)	
97:1	150-160	1	Fish hook	Trochidae	*Trochus sp.*			x
99:1	150-160	4	Worked shell	Cypraeidae	*Monetaria*	moneta	Dorsal surface re-moved	x
99:2	150-160	3	Fish disc	Conidae	*Conus sp.*		Perforation (central)	
100:1	150-160	4	Pendant (poss.)	Pteriidae				x
100:2	150-160	4	Ring/bracelet (large)	Conidae	*Conus sp.*			
100:3	150-160	4	Ring/bead (small)	Conidae	*Conus sp.*			
101:1	150-160	5	Fish hook	Trochidae			Possible Trochus	
102:1	150-160	6	Abrader (poss.)	Urchin Spine			Distal tip	x
103:1	150-160	7	Ring	Conidae	*Conus sp.*			
105:1	160-170	1	Worked shell	Conidae	*Conus*	litteratus		x
106:1	160-170	2	Ring/bead (small)	Conidae	*Conus sp.*			
106:2	160-170	2	Ring/bead (small)	Conidae	*Conus sp.*			
107:1	160-170	3	Ring/bead (small)	Conidae	*Conus sp.*			
108:1	160-170	4	Fish hook	Pteriidae/ Trochidae				x

Cat. no.	Depth (cm)	Unit	Category	Family	Genus	Species	Comment	Photo
108:2	160-170	4	Fish hook	Pteriidae/ Trochidae				x
108:3	160-170	4	Ring/bead (small)	Conidae	*Conus sp.*			
110:1	160-170	6	Worked shell	Arcidae	*Anadara*	antiquata		x
112:1	160-170	8	Ring/bead (small)	Conidae	*Conus sp.*			
113:1	170-180	1	Ring	N/A				
114:1	170-180	2	Worked shell	Nautilidae	*Nautilis sp.*			x
114:2	170-180	2	Worked shell	Pteriidae			Possible blank	x
114:3	170-180	2	Worked shell	N/A			Perforation (central)	
114:4	170-180	2	Ring/bead (small)	Conidae	*Conus sp.*			
115:1	170-180	3	Bead (small)	Conidae	*Conus sp.*			
116:1	170-180	4	Ring	Conidae	*Conus sp.*			
116:2	170-180	4	Ring	Conidae	*Conus sp.*			
117:1	170-180	5	Fish hook	Conidae	*Conus sp.*			x
119:1	170-180	7	Ring/bead (small)	Conidae	*Conus sp.*			
120:1	170-180	8	Bead/lure	Cypraeidae			Dorsal surface re-moved	x
122:1	180-190	2	Worked shell	Tridacnidae /Arcidae				x
122:2	180-190	2	Ring/bracelet (large)	Conidae	*Conus sp.*			x
123:1	180-190	3	Ring/bead (small)	Conidae	*Conus sp.*			
124:1	180-190	4	Bead/lure (small)	Cypraeidae	*Monetaria*	moneta	Dorsal surface re-moved	x
124:2	180-190	4	Ring/bead (small)	Conidae	*Conus sp.*			
125:1	180-190	5	Worked shell	Nautilidae/ Pteriidae				x
125:2	180-190	5	Fish hook	Conidae	*Conus sp.*			x
125:3	180-190	5	Ring/bead	Conidae	*Conus sp.*			
125:4	180-190	5	Bead (medium)	Conidae	*Conus sp.*			
126:1	180-190	6	Bead (medium)	Conidae	*Conus sp.*			
127:1	180-190	7	Ring/bead (large)	Conidae	*Conus sp.*			
127:2	180-190	7	Ring/bead (large)	Conidae	*Conus sp.*			
127:3	180-190	7	Worked shell	Pteriidae				
127:4	180-190	7	Worked shell	Pteriidae				
127:5	180-190	7	Ring/bead (small)	Conidae	*Conus sp.*			
128:1	180-190	8	Ring/bead (small)	Conidae	*Conus sp.*			
129:1	190-200	1	Ring/bead (small)	Conidae	*Conus sp.*			
130:1	190-200	2	Ring/bead (small)	Conidae				
130:2	190-200	2	Ring/bead (small)	Conidae				
130:3	190-200	2	Ring/bead (small)	Conidae				
130:4	190-200	2	Ring/bead (small)	Conidae				
130:5	190-200	2	Ring/bead (small)	Conidae				
130:6	190-200	2	Bead (medium)	Pteriidae				
130:7	190-200	2	Fish hook	Pteriidae/ Trochidae			J-shaped	
130:8	190-200	2	Ring/bead (small)	Conidae	*Conus sp.*			
130:9	190-200	2	Ring/bead (small)	Conidae	*Conus sp.*			
131:1	190-200	3	Ring/bracelet (large)	Conidae	*Conus sp.*			x

Cat. no.	Depth (cm)	Unit	Category	Family	Genus	Species	Comment	Photo
131:2	190-200	3	Abrader (prob.)	Urchin Spine				x
131:3	190-200	3	Disc	Conidae	*Conus sp.*		Perforation (central)	x
131:4	190-200	3	Ring/bead (small)	Cypraeidae				
131:5	190-200	3	Ring/bead (small)	Nassaridae				
131:6	190-200	3	Ring/bead (small)	Conidae	*Conus sp.*			
131:7	190-200	3	Ring/bead (small)	Conidae	*Conus sp.*			
131:8	190-200	3	Ring/bead (small)	Conidae	*Conus sp.*			
131:9	190-200	3	Ring/bead (small)	Conidae	*Conus sp.*			
131:10	190-200	3	Ring/bead (small)	Conidae	*Conus sp.*			
131:11	190-200	3	Ring/bead (small)	Conidae	*Conus sp.*			
131:12	190-200	3	Ring/bead (small)	Conidae	*Conus sp.*			
131:13	190-200	3	Ring/bead (small)	Conidae	*Conus sp.*			
132:1	190-200	4	Worked shell	Cypraeidae	*Cypraea*	tigris	Possible pendant	x
132:2	190-200	4	Ring/bead (small)	Conidae	*Conus sp.*			
133:1	190-200	5	Ring	Conidae	*Conus sp.*			
133:2	190-200	5	Ring	Conidae	*Conus sp.*			
134:1	190-200	6	Ring/bead (small)	Conidae	*Conus sp.*			
134:2	190-200	6	Abrader (poss.)	Urchin Spine				
134:3	190-200	6	Disc	Conidae	*Conus*	litteratus	Perforation (central)	
136:1	190-200	7	Ring/bead (small)	Conidae	*Conus sp.*			
136:2	190-200	7	Ring/bead (small)	Conidae	*Conus sp.*			
136:3	190-200	7	Ring/bead (small)	Conidae	*Conus sp.*			
137:1	190-200	8	Ring/bead (small)	Conidae	*Conus sp.*			
137:2	190-200	8	Ring/bead (small)	Conidae	*Conus sp.*			
139:1	200-210	2	Ring/bead (small)	Conidae	*Conus sp.*			
140:1	200-210	3	Ring/bead (small)	Conidae	*Conus sp.*			
141:1	200-210	4	Worked shell	Pteriidae	*Pinctada*	margaritif-era		x
141:2	200-210	4	Ring/bead (small)	Conidae	*Conus sp.*			
141:3	200-210	4	Ring/bead (small)	Conidae	*Conus sp.*			
142:1	200-210	5	Worked shell	Conidae	*Conus*	gloriamaris		x
143:1	200-210	6	Worked shell	Pteriidae			Possible preform pendant	x
143:2	200-210	6	Pendant	Pteriidae				x
144:1	200-210	7	Ring/bead (small)	Conidae	*Conus sp.*			
145:1	200-210	8	Ring/bead (small)	Conidae	*Conus sp.*			
146:1	210-220	1	Ring/bead (small)	Conidae	*Conus sp.*			
146:2	210-220	1	Ring/bead (small)	Conidae	*Conus sp.*			
147:1	210-220	2	Ring/bead (small)	Conidae	*Conus sp.*			
147:2	210-220	2	Ring/bead (small)	Conidae	*Conus sp.*			
147:3	210-220	2	Ring/bead (small)	Conidae	*Conus sp.*			
148:1	210-220	3	Bead/lure	Cypraeidae	*Monetaria*	moneta	Dorsal surface re-moved	
150:1	210-220	5	Worked shell	Urchin Spine (poss.)				x

Cat. no.	Depth (cm)	Unit	Category	Family	Genus	Species	Comment	Photo
151:1	210-220	6	Ring/bracelet (large)	Conidae	*Conus sp.*			x
153:1	210-220	8	Bead (blank)	Pteriidae				x
154:1	220-230	1	Ring/bead (small)	Conidae	*Conus sp.*			
154:2	220-230	1	Worked shell	Cypraeidae	*Monetaria*	moneta	Dorsal surface removed	
155:1	220-230	2	Bead (small)	Cypraeidae				x
155:2	220-230	2	Bead/lure	Cypraeidae			Dorsal surface removed	x
155:3	220-230	2	Worked shell	Pteriidae	*Pinctada sp.*		Worked around lateral margins, possible blank	x
155:4	220-230	2	Ring/bead (small)	Conidae	*Conus sp.*			
155:5	220-230	2	Ring/bead (small)	Conidae	*Conus sp.*			
155:6	220-230	2	Ring/bracelet (large)	Conidae	*Conus sp.*			x
155:7	220-230	2	Ring/bracelet (large)	Conidae	*Conus sp.*			
155:8	220-230	2	Bead (blank)	Pteriidae			Perforation	x
155:9	220-230	2	Bead (blank)	Pteriidae			Perforation	
156:1	230-240	1	Disc/pendant	Cypraeidae	*Cypraea*	Tigris	Two perforations. Dated WK 23770	x
156:2	230-240	1	Ring/bracelet (large)	Conidae				x
156:3	230-240	1	Disc	N/A			Perforation (incomplete, near umbo, bivalve)	x
156:4	230-240	1	Ring/bead (small)	Conidae	*Conus sp.*			
156:5	230-240	1	Ring/bead (small)	Conidae	*Conus sp.*			
157:1	220-230	3	Worked shell	Pteriidae				x
157:2	220-230	3	Bead (blank)	Trochidae	*Trochus sp.*			x
157:3	220-230	3	Disc/pendant	Conidae	*Conus sp.*		Perforation	x
157:4	220-230	3	Fish hook	N/A			Fish hook form (ID-Pat O'Dea)	
157:5	220-230	3	Ring/bead (small)	Conidae	*Conus sp.*			x
157:6	220-230	3	Ring/bead (small)	Conidae	*Conus sp.*			x
157:7	220-230	3	Ring/bead (small)	Conidae	*Conus sp.*			x
157:8	220-230	3	Ring/bead (small)	Conidae	*Conus sp.*			x
157:9	220-230	3	Ring/bead (small)	Conidae	*Conus sp.*			
158:1	220-230	4	Scraper (poss.)	Cypraeidae	*Cypraea*	Tigris	Large piece of modified cowry fossula	x
158:2	220-230	4	Disc	Conidae	*Conus sp.*		Perforation (central)	x
159:1	220-230	5	Ring/bead (small)	Conidae				x
159:2	220-230	5	Ring/bead (medium)	Conidae				x
159:3	220-230	5	Disc	Conidae	*Conus*	litteratus	Perforation (central)	x
160:1	220-230	6	Worked shell	?Arcidae	*Andara*	antiquata		x
160:2	220-230	6	Ring/bead (small)	Conidae				
161:1	230-240	2	Ring/bead (small)	Conidae	*Conus sp.*			
161:2	230-240	2	Ring/bead (small)	Conidae	*Conus sp.*			
161:3	230-240	2	Ring/bead (small)	Conidae	*Conus sp.*			
161:4	230-240	2	Ring/bracelet (large)	Conidae	*Conus sp.*			
161:5	230-240	2	Ring/bead (small)	Conidae	*Conus sp.*			
161:6	230-240	2	Ring/bead (small)	Conidae	*Conus sp.*			

Cat. no.	Depth (cm)	Unit	Category	Family	Genus	Species	Comment	Photo
161:7	230-240	2	Ring/bead (small)	Conidae	*Conus sp.*			
162:1	230-240	3	Ring/bead (small)	Conidae	*Conus sp.*			
162:2	230-240	3	Ring/bead (small)	Cypraeidae				
162:3	230-240	3	Disc	Conidae	*Conus sp.*		Perforation (central)	
163:1	230-240	4	Ring	Conidae				
163:2	230-240	4	Disc	Conidae				
163:3	230-240	4	Worked shell (poss.)	Cypraeidae	*Monetaria*	moneta	Possible incision	
165:1	240-250	2	Ring	N/A				
165:2	240-250	2	Ring	N/A				
165:3	240-250	2	Ring	N/A				
165:4	240-250	2	Ring	N/A				
165:5	240-250	2	Worked shell	N/A				
166:1	240-250	3	Disc	Conidae	*Conus sp.*		Perforation (central, large)	
169:1	240-250	4	Ring	Conidae	*Conus sp.*		Dated WK-23771	x
169:2	240-250	4	Ring	Conidae	*Conus sp.*			x
169:3	240-250	4	Ring	Conidae	*Conus sp.*			
170:1	230-240	5	Disc	Conidae	*Conus sp.*		Perforation (central)	x
170:2	230-240	5	Abrader (prob.)	Urchin Spine				x
170:3	230-240	5	Fish hook	Pteriidae/ Trochidae			J-shaped	x
170:4	230-240	5	Disc	Conidae	*Conus sp.*		Perforation (central, incomplete)	
171:1	230-240	6	Abrader	Urchin				x
171:2	230-240	6	Worked shell	Pteriidae	*Pinctada*	margaritif-era	Possible blank	x
171:3	230-240	6	Fish hook	Pteriidae/ Trochidae			J-shaped	x
171:4	230-240	6	Ring/bead (small)	Conidae	*Conus sp.*			
172:1	240-250	5	Ring	Conidae	*Conus sp.*		Broken, two fragments	x
172:2	240-250	5	Ring	Conidae	*Conus sp.*			
172:3	240-250	5	Worked shell	Pteriidae	*Pinctada*	margaritif-era		
173:1	240-250	6	Bead/lure	Cypraeidae	*Monetaria*	moneta	Dorsal surface re-moved, perforation	
173:1	240-250	6	Worked shell	Cypraeidae			Dorsal surface re-moved	
176:1	250-260	6	Worked shell	Cypraeidae			Dorsal surface re-moved	x
Feature H:1	170-180	7	Ring/bracelet (large)	Conidae	*Conus sp.*			x
Feature K:1			Adze	Conidae	*Conus sp.*		Fragment	
Feature K:2			Ring/bead (small)	Conidae	*Conus sp.*			
Feature K:3			Ring					
Feature K:4			Ring					


Arcidae
Conidae
Cypraeidae
Nassaridae
Pteriidae
Trochidae
Pteriidae/Trochidae
Tridacnidae
Urchin
n = 129
n = 65
n = 29
c. 3300 -
3000 cal. BP
c. 3000 -
2700 cal. BP
c. 2700 BP -
Latte Period

Scale 1:1